Forest Health Assessment and Plan for the 2006-2007 project area of Mount Spokane State Park

Pacific Biodiversity Institute

Due to the large size of this document, only relevant portions referenced in the EIS are included in this Appendix. The document may be found in its entirety online at:
http://www.pacificbio.org/publications/vegetation/state_parks/wa_east/Mt_Spokane_Forest_Health_Report_2007.pdf

The Forest Condition Survey

Methods

During the fall of 2006 and late spring of 2007, we inventoried 406 forest condition assessment plots across 4,250 acres in Mt. Spokane State Park, or one plot for every 10.5 acres of the project area. The idea behind a survey of this intensity was to build a detailed spatial dataset realistically representing the on-the-ground conditions of the landscape in the project area. This dataset assisted us in evaluating, at a fine spatial scale, the factors influencing fire hazard, forest health condition, and wildlife habitat condition. Using these data, we were able to draw objective conclusions about the condition of forest ecosystems at Mt. Spokane, and we were able to understand the magnitude and spatial distribution of forest health elements across the landscape.

The survey methods and targeted variables of the forest inventory were initially defined by Washington State Parks. Some adaptations to the original survey protocols were made, and new protocols were added as the surveys progressed due to a better understanding of real forest conditions in the survey area. The following section details our methods and protocols in the forest condition survey as they were followed at the termination of our fieldwork sessions on June 1, 2007.

The delineation of forested stands in the project area

We delineated forest stands in the original treatment areas proposed by Washington State Parks (Figure 1) using the guidelines set forth in the original project proposal. Stand delineation was conducted remotely prior to any of our staff actually visiting the project area during this project. We used digital satellite imagery, digital elevation models (DEMs), color stereo air photographs, agency provided GIS data (including color orthophotographs, topographic maps, and priority habitat data), and a Natural Forest Inventory conducted by the Department of Natural Resources (DNR) Natural Heritage Program in 1992 to aid in the delineation of forest stands.

We were requested to delineate forest stands between 75-125 acres in size. These stands were meant to be relatively homogenous in species composition, age, structure, understory vegetation, and physical attributes (slope, aspect, soils). In some cases, stands smaller than 75 acres were delineated where the characteristics of the stand were clearly different than that in the surrounding forest (e.g. a pocket of old growth or balds). Stands in excess of 125 acres were delineated in select situations where forest conditions appeared very homogeneous.

Figure 8 illustrates the layout of the stand boundaries resulting from our remote spatial data analysis. Figure 9 illustrates the layout of stands in the actual project area pertaining to this report.

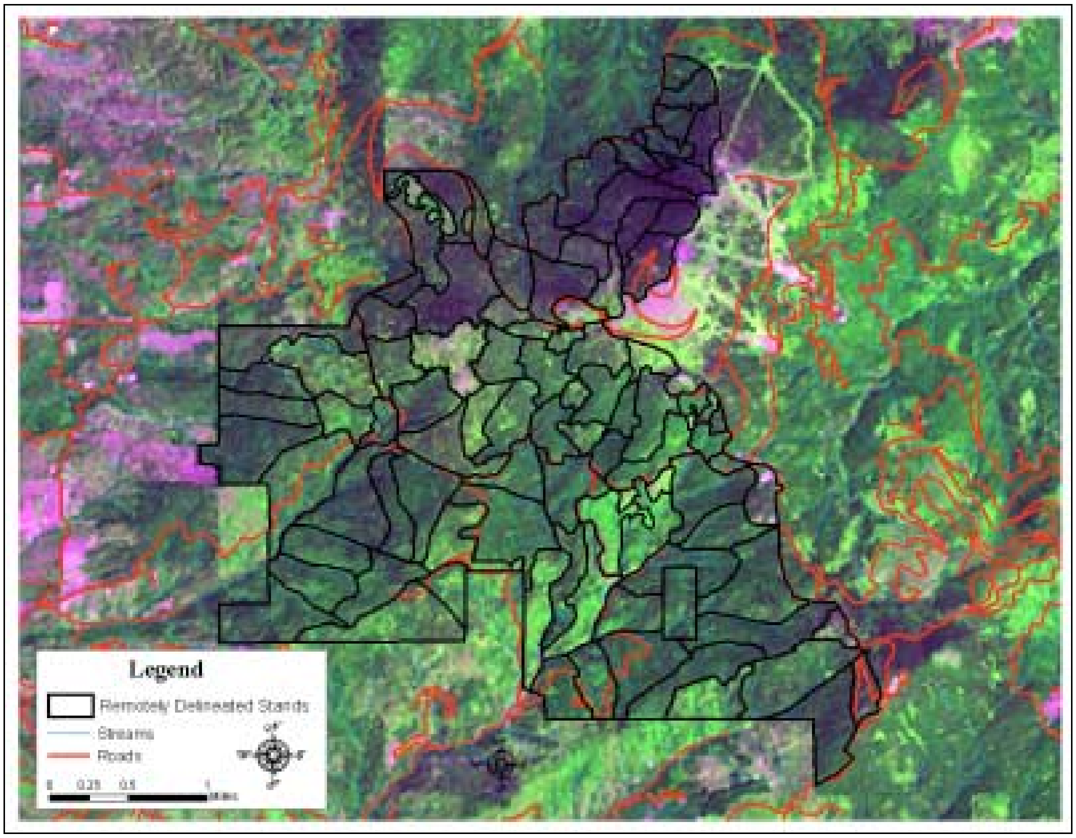

Figure 8. Location of all forest stands mapped in 2006.

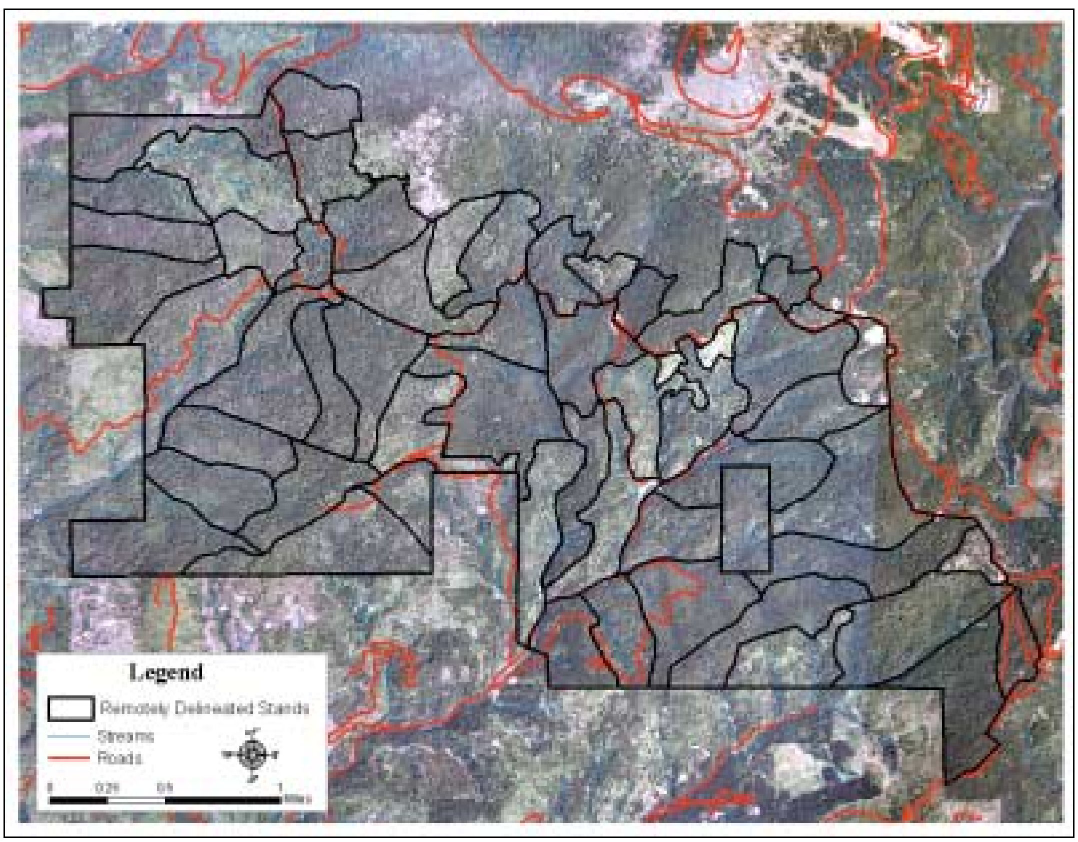

Figure 9. Location of forest stands in the project area mapped in 2006.

Field Surveys

Field surveys consisted of measuring discreet data within variable and fixed-radius plot locations throughout the project area. We also collected a standardized set of stand level data compliant with the Vegetation Polygon Forms provided by Washington State Parks and used as a vegetation community inventory field form throughout the Washington State Parks system. The guidelines used to complete all of the survey types mentioned were provided to us by Washington State Parks.

The forest condition survey plots were established along a randomly generated, systematic plot grid that covered the areas to be surveyed. This systematic grid and the approximate location of each plot were provided to PBI by Washington State Parks. Some plots in the systematic grid fell very close to stand boundaries or ownership or project area boundaries. These plots were moved from these locations (typically 100 ft towards the interior of the stand in question) so that they would fall entirely within the stand that was to be sampled. Figure 10 illustrates this situation. The initial sampling protocol called for using variable radius plot with a basal area factor (BAF) of 10, so this factor was used to determine if plots might straddle polygon boundaries. The initial sampling protocol called for in the RFP was modified to use other BAFs in dense stands (as described below), but this could not be predetermined. Therefore it was assumed for the purpose of plot layout that all plots might use a BAF 10 variable radius.

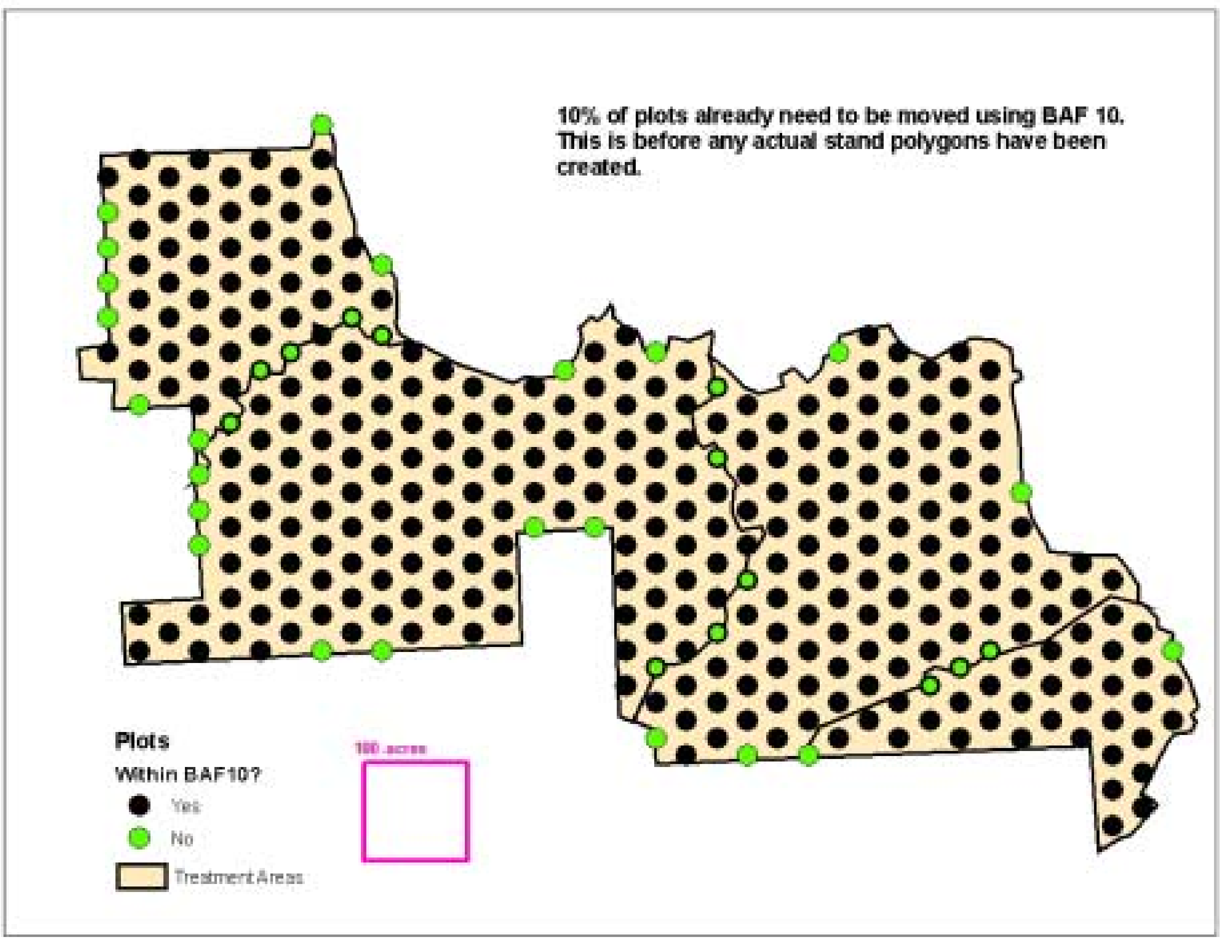

Figure 10. Map providing an example of the problem faced with ensuring that the systematic plot grid-sampling scheme didn't create "edge" plots where data would have been measured from two distinct areas.

We used topographic maps, aerial maps, compasses, and hand-held GPS units to locate the plots. Once arriving at the assigned plot, GPS accuracy was calculated by waypoint averaging. We strove to locate the plots within 20 feet of the assigned location. GPS reception was very poor in some locations due to tree canopies and obstruction from adjacent hillslopes. Figure 11 illustrates the resulting layout of the 406 plots we surveyed during this project.

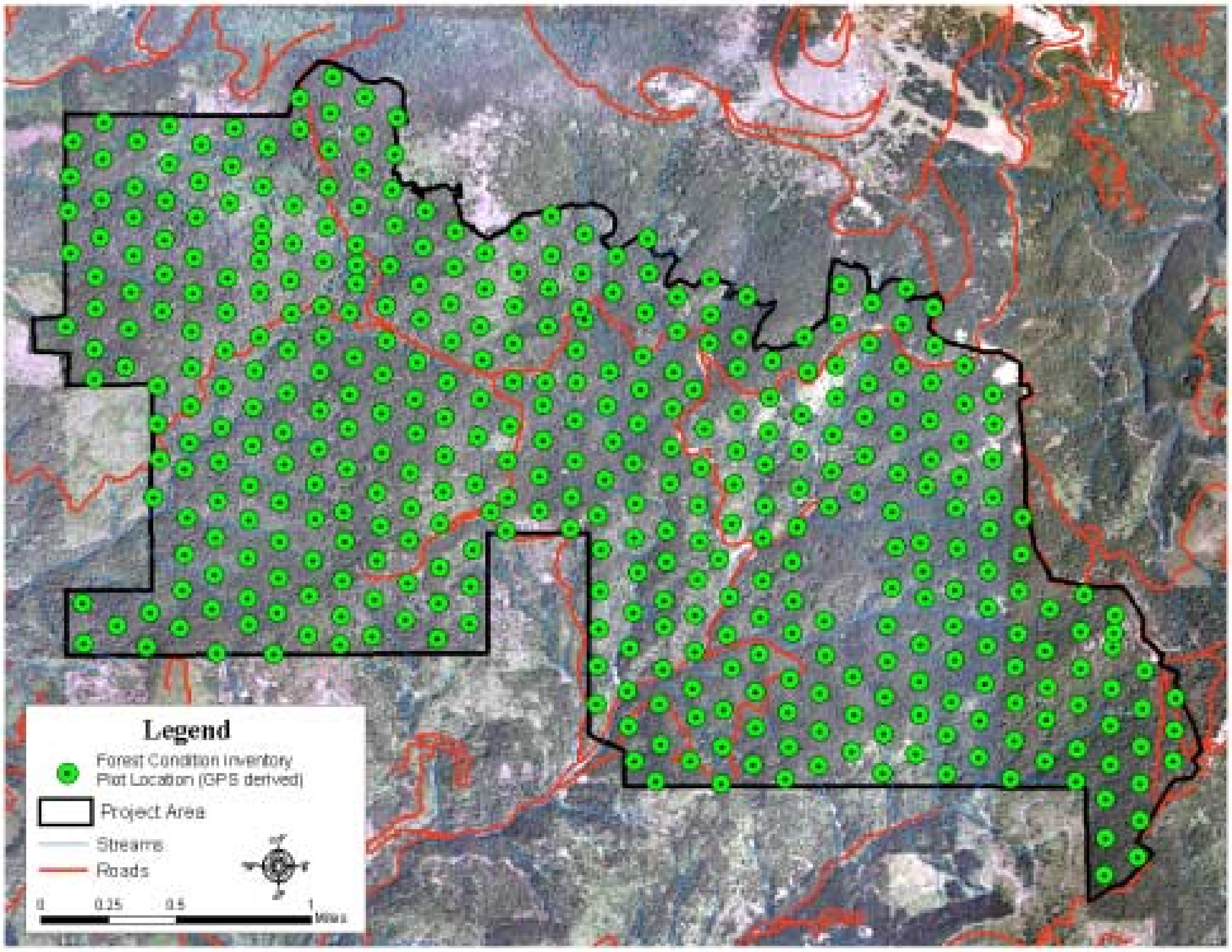

Figure 11. Layout of the 406 forest conditions survey plots inventoried by PBI staff during the fall of 2006 and late spring of 2007. The open area in the central-eastern part of this figure is a private inholding and was not a part of the study.

At each plot, we recorded information on physical characteristics, overstory characteristics, mid- and understory characteristics, coarse woody debris, fire behavior fuel model, dominant plant associations and selected vegetation attributes. We also photographed representative vegetation and noted signs of wildlife-use of the habitat in or near the plots.

We collected data on all the stand attributes specified in our contract using a combination of fixed (0.05 acre) and variable radius plots. A detailed description of the sampling methods is outlined below. For the variable radius plots, we used an appropriate Basal Area Factor (BAF) for each stand condition that we encountered. Our default BAF was 10. We used a BAF of 20 if a BAF of 10 pulled in more than 15 trees into a plot. In a few plots, a BAF of 40 was used if greater than 15 trees were in the plot using a BAF of 20. Table 2 shows the number of plots that used each Basal Area Factor prism.

Table 2. Number of plots using a given Basal Area Factor.

BAF Prism Used	Number of Plots	Percent of Total Plots
10	123	30%
20	275	68%
40	7	2%

All trees identified as being "in" in the variable radius plots were identified to species, measured to the nearest inch for the diameter at breast height (DBH), and measured to the nearest foot for the total tree height (HT). We also measured to the nearest foot the distance from the forest floor to the nearest live branches on an "in" tree to get crown heights (directly related to crown depth). Details of our surveying methods for stand characteristics are described below. A copy of the survey instructions and guidelines used by the field crew is included in this report as Appendix A.

The following stand characteristics were observed and recorded at each plot:

1. Physical attributes

- GPS location – the location of each plot center was recorded by a handheld GPS unit and given a specific waypoint name. The location accuracy was calculated by waypoint averaging. We allowed the GPS unit to run for the duration of our survey at each plot to calculate the average location of the field plot. We attempted to locate the field plot to within 20 feet of the assigned location in the systematic grid provided by Washington State Parks.
- Elevation, slope and aspect of the plot were derived via an automated ArcMap function using waypoints of our recorded GPS locations overlaid on a high-resolution digital elevation model.

2. Overstory characteristics (variable plots for all "in trees")

- Species – tree species were identified and recorded in plot forms as 4-letter alpha codes.
- Diameter at breast height (DBH in inches) – the DBH was measured to the nearest inch with a DBH tape. In cases where two trees were growing together, we measured individual trunks as two separate trees if they split below breast height (4.5 feet) or recorded a single tree if they split above the breast height.
- Total height (feet) – we used electronic clinometers to measure tree heights to the nearest foot. The distance from the trunk of the tree was measured using a logger's tape or a calibrated string and entered into the electronic clinometer. Height was then calculated automatically by the clinometer. After some familiarity with the heights in each plot measured by the clinometer, our crew was able to visually estimate some tree heights to efficiently complete plot surveys.
- Height to live crown – we measured the height to the lowest, significant live branches of each tree.
- Dominance (D, CD, I, S) – Trees were classified into four classes: Dominant, Co-dominant, Intermediate, and Suppressed. Dominant trees are usually the tallest trees with crowns emergent above the surrounding canopy. These trees have full access to light and are not shaded by any other trees. Co-dominant trees share the canopy with other trees. Trees classified as intermediate are usually shorter in height than the two previous classes,

with light limitations due to shading from D and CD trees. Intermediate and taller trees suppress the growth of smallest trees by limiting light and space.

- Canopy closure (densiometer) – overstory density was measured with a spherical densiometer. Four readings of North, East, South, and West were taken at each plot from the plot center. We assumed four equi-spaced dots in each square of the grid and counted dots that represent canopy openings. The total count was used in our analysis to calculate the percent of area covered by live forest canopy.
- Snags – we recorded the species name and measured the height, DBH, and decay class for each snag that was considered "in".
    - Species – the species of snags were identified by observations of bark and trunk characteristics.
    - Height (of those > 6 ft) – Snag height was measured by clinometers or estimated visually.
    - DBH (of those > 4 inches DBH) – the DBH of snags was measured with a DBH tape.
    - Decay class – We followed the guidelines from Washington Department of Natural Resources (2004. Natural Resources Field Procedures: Forest resource inventory system. FRIS Ver. 1.31. Feb. 04.) to categorize snags into four decay classes (1 to 4) based on characteristics such as the presence and amount of bark left on the trunk, the presence and size of twigs and branches, and the texture, shape, and color of the wood.

3. Mid- and understory characteristics (in a 0.05 ac [26.33 ft radius] plot surrounding the plot center)

- We identified and visually estimated the percent cover and maximum height for the 3 most abundant understory and shrub species. We estimated, using an ocular count, the total number of shrub species present.

4. Coarse woody debris (CWD) (in a 0.05 ac plot)

- We recorded the number of pieces that were > 6 inches in diameter at largest end (where the large end falls into the plot). The decay class was recorded based on guidelines from Washington Department of Natural Resources (2004. Natural Resources Field Procedures: Forest resource inventory system). FRIS Ver. 1.31. Feb. 04.). We also estimated the percent of each plot covered by the tallied CWD.

5. Fire behavior fuel model (Scott and Burgan 2005)

- We recorded the fire behavior fuel model, or combination of models that best described the fuel conditions at each plot.

6. Vegetation associations

- Beginning with the first plot in each stand, information was gathered about the dominant vegetation associations and select vegetation attributes found in the stand. Vegetation plant associations were assessed according to Williams et al. (1995) or Cooper et al. (1987). A key to the plant associations of the project area is provided in Appendix L.

Data Analysis Methods

PBI staff and interns entered the forest condition plot data into a Microsoft Access database. In the database suitable values were automatically converted to a per acre basis based on forest inventory statistical procedures (for example – trees per acre, tree species per acre, CWD stems per acre, etc.). The following forest characteristic indices were also calculated with the data following standardized calculation techniques.

- Quadratic Mean Diameter (QMD)
- Stand Density Index (SDI)
- Shannon Diversity Index (Shannon-DBH and Shannon-species)
- Canopy Bulk Density (CBD)
- Canopy Height (CH)
- Canopy Base Height (CBH)
- Trees Per Acre (TPA)
- Basal Area per Acre (BA)
- Understory Mean Height (UMH)

The generated statistics were attributed to each plot and incorporated into tables for processing in various models and data analysis programs used to help understand potential fire behavior, predicted fire effects, wildlife habitat suitability, and forest health issues.

The data we collected at each plot were initially assigned to a point location for the plot center. However, the plot data represent a sample of the forest characteristics of a large area surrounding the plot center. To better assess the spatial distribution of the forest characteristics of the survey plots, we converted the plot data for each point into a grid surface layer using the inverse distance weighted (IDW) interpolation method build into ESRI's ArcGIS Spatial Analyst (ESRI 2007).

"IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. To predict a value for any unmeasured location, IDW will use the measured values surrounding the prediction location. Those measured values closest to the prediction location will have more influence on the predicted value than those farther away. Thus, IDW *(interpolation)* assumes that each measured point has a local influence that diminishes with distance. It weights the points closer to the prediction location greater than those farther away, hence the name inverse distance weighted." (ESRI 2007).

The maps created using the IDW technique illustrate the distribution of the most important forest condition attributes across the entire study area. To create these maps we used a power factor of 1, a cell size of 30-meters (100 feet) and a search neighborhood of 7 plots (a central plot plus six surrounding plots) (points). The resulting grids were used in subsequent analysis and assessment of forest health conditions and wildlife habitat conditions.

Results

Vegetation Plot and Polygon Data Summary

We surveyed and analyzed the data from all 406 forest-condition survey plots and collected data on the 56 remotely delineated forest stands. The results of our data collection and statistical processing are discussed below for the following forest condition attributes:

- Plant associations
- Fuel models
- Canopy cover
- Canopy bulk density
- Canopy height
- Canopy base height
- Tree density
- Stand density index
- Basal area
- Quadratic mean diameter
- Maximum diameters of trees meeting potential old-growth criteria (> 8 trees per acre)
- Tree diameter distributions
- Tree species composition and diversity
- Tree dominance classes
- Distribution of snags and coarse woody debris (CWD)
- Understory shrub cover
- Cover and density of small trees

These data were mapped based on analysis of the forest survey plot data across the study area as determined by IDW interpolation and are presented in Figures 12-34 (except for the small tree data – see Figures 97 and 98). These data are also presented in a tabular form as calculated for each plot in Appendix M.

Plant Associations

We found 14 different plant associations in the project area during our forest survey (Figure 12 and Table 3). Most of these plant associations are in the grand fir zone. However, many are in the wetter western hemlock zone. A few plots fell into the subalpine fir zone, a few were Douglas-fir series or western redcedar series plant associations and a few were non-forest plant associations. Further discussion of the distribution of plant associations is presented later in the report (see Table 15 and Figure 89). A key to the plant associations of the project area is provided in Appendix L.

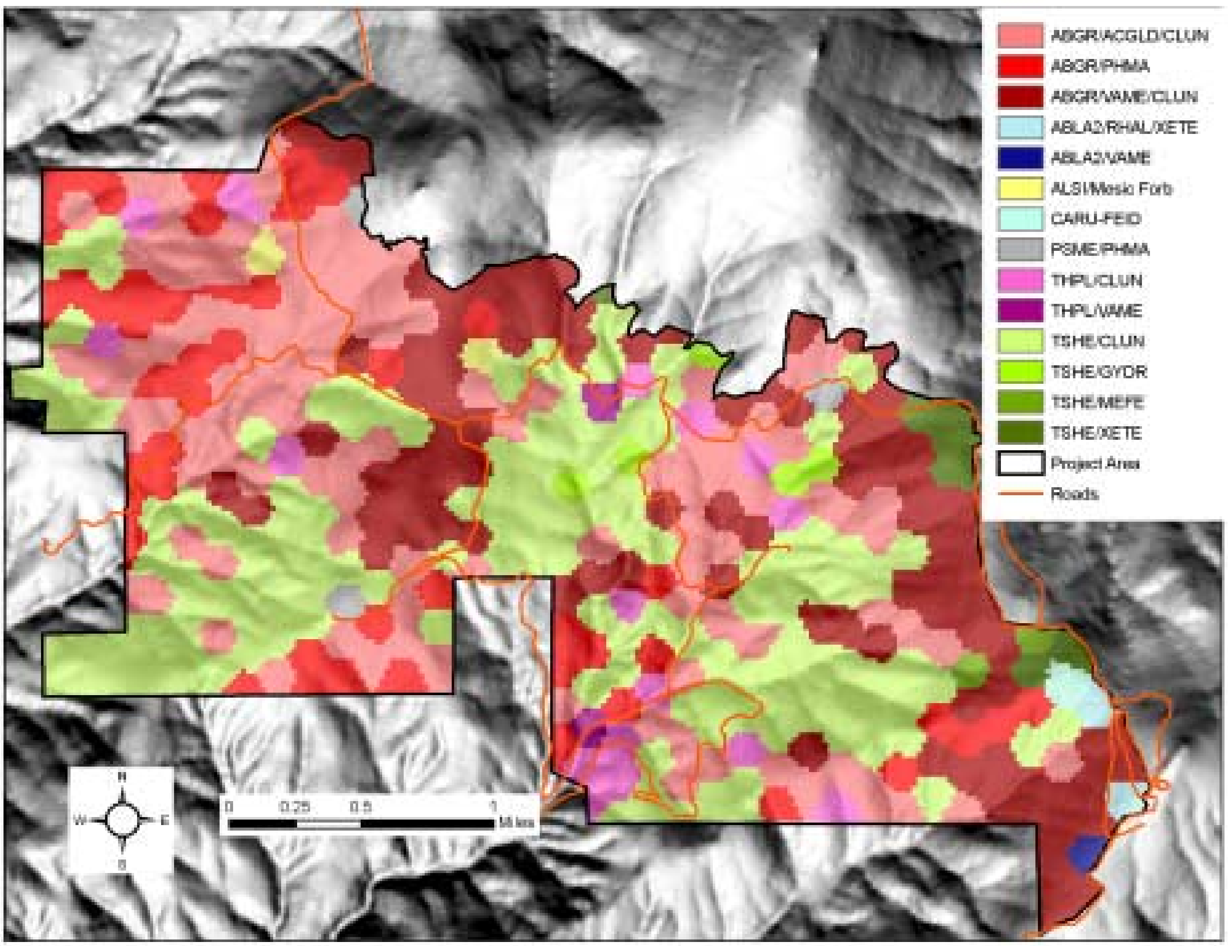

Figure 12. Plant associations occurring in the project area. (see Table 3 for key to codes)

Table 3. Plant associations found in the project area.

Common Name	Scientific Name	Abbreviation	Global Rarity Rank
Grand fir / Douglas maple / queen's Cup	*Abies grandis / Acer glabrum / Clintonia uniflora*	ABGR/ACGLD/CLUN	G3
Grand fir / mallow-leaf ninebark	*Abies grandis / Physocarpus malvaceus*	ABGR/PHMA	G3
Grand fir / thinleaf huckleberry / queen's cup	*Abies grandis / Vaccinium membranaceum / Clintonia uniflora*	ABGR/VAME/CLUN	G3G4
Subalpine fir / cascade azalea / beargrass	*Abies lasiocarpa / Rhododendron albiflorum / Xerophyllum tenax*	ABLA2/RHAL/XETE	G5-S3
Subalpine fir / thinleaf huckleberry	*Abies lasiocarpa / Vaccinium membranaceum*	ABLA2/VAME	G4
Sitka alder / mesic forb	*Alnus sinuata /* mesic forb	ALSI/Mesic Forb	G3G4
Pinegrass / Idaho fescue	*Calamagrostis rubescens / Festuca idahoensis*	CARU-FEID	no NatureServe listing
Douglas-fir / mallow-leaf ninebark	*Pseudotsuga menziesii / Physocarpus malvaceus*	PSME/PHMA	G5
Western redcedar / queen's cup	*Thuja plicata / Clintonia uniflora*	THPL/CLUN	G4
Western redcedar / thinleaf huckleberry	*Thuja plicata / Vaccinium membranaceum*	THPL/VAME	G3G4
Western hemlock / queen's cup	*Tsuga heterophylla / Clintonia uniflora*	TSHE/CLUN	G4-S4
Western hemlock / northern oak fern	*Tsuga heterophylla / Gymnocarpium dryopteris*	TSHE/GYDR	G3G4
Western hemlock / rusty menziesia	*Tsuga heterophylla / Menziesia ferruginea*	TSHE/MEFE	G2
Western hemlock / beargrass	*Tsuga heterophylla / Xerophyllum tenax*	TSHE/XETE	G2

Global Rank Codes	State Rank Codes
G2 = Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range. (6 to 20 occurrences or few remaining individuals or acres).	**S3** = Rare or uncommon in the state. (Typically 21 to 100 occurrences)
G3 = Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single western state, a physiographic region in the East) or because of other factors making it vulnerable to extinction throughout its range. (21 to 100 occurrences)	**S4** = Widespread, abundant, and apparently secure in state, with many occurrences, but the taxon is of long-term concern. (Usually more than 100 occurrences)
G4 = Widespread, abundant, and apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery. Thus, the Element is of long-term concern. (Usually more than 100 occurrences)	**Note: Global Rarity Ranks are from natureserve.org State Rank Codes are from Washington Dept of Natural Resources Natural Heritage program**
G5 = Demonstrably widespread, abundant, and secure globally, though it may be quite rare in parts of its range, especially at the periphery.	

Fire Behavior Fuel Models

In this project, we used a new set of standard fire behavior fuel models developed by Scott and Burgan (2005) for use with Rothermel's surface fire spread model. Fuel models have long been used to help predict the potential behavior and effects of wildland fire. The original set of 13 fuel models (Albini 1976) have been replaced by the new set of 40 fuel models developed by Scott and Burgan.

The fire behavior fuel models used in this project are designed as input to the Rothermel (1972) fire spread model, which is used in many fire behavior-modeling systems. "The fire behavior fuel model input set includes:

- Fuel load by category (live and dead) and particle size class (0 to 0.25 inch, 0.25 to 1.0 inch, and 1.0 to 3.0 inches diameter)
- Surface-area-to-volume (SAV) ratio by component and size class
- Heat content by category
- Fuelbed depth
- Dead fuel moisture of extinction" (Scott and Burgan 2005).

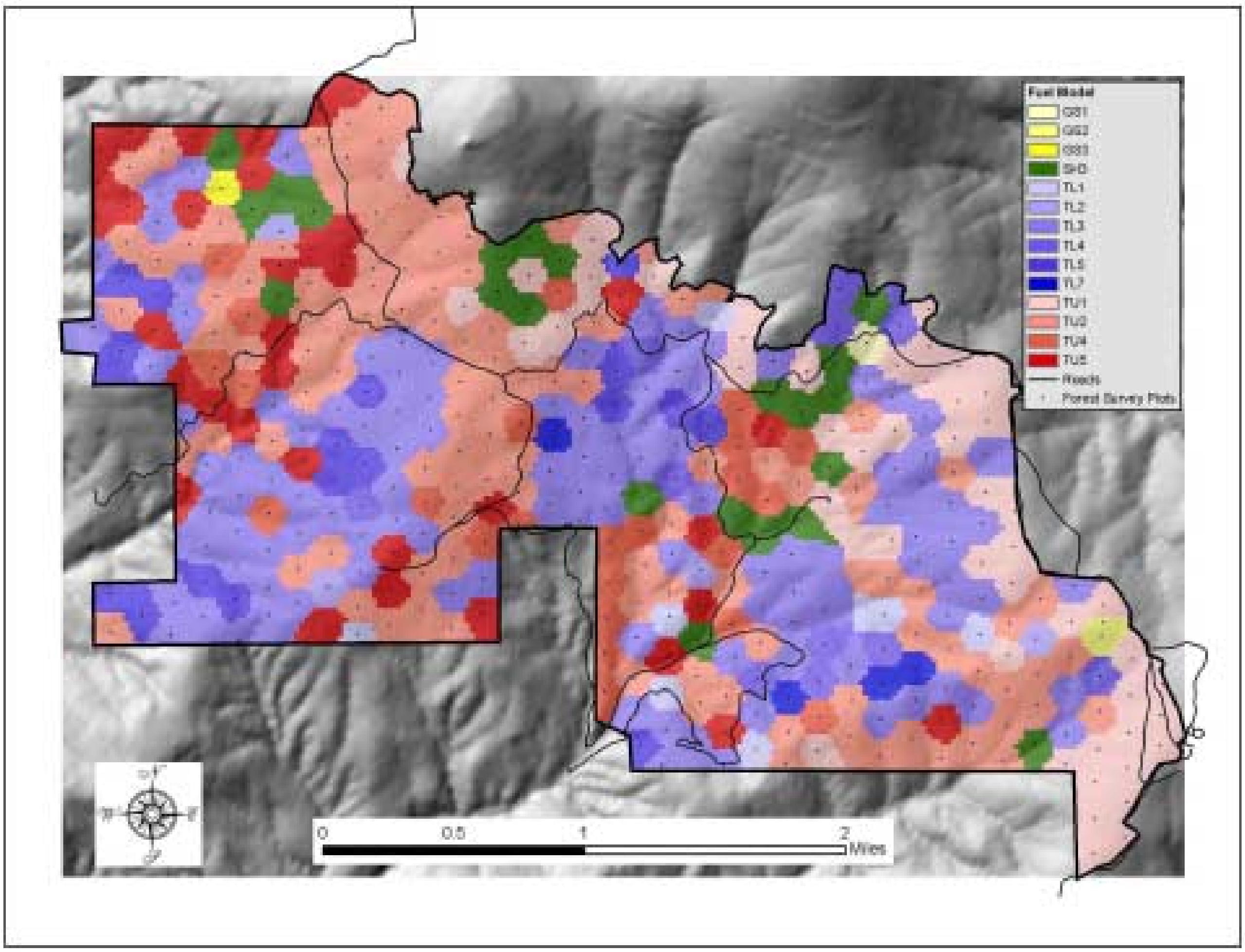

Figure 13. Fire behavior fuel models occurring in the project area. (Scott and Burgan 2005)

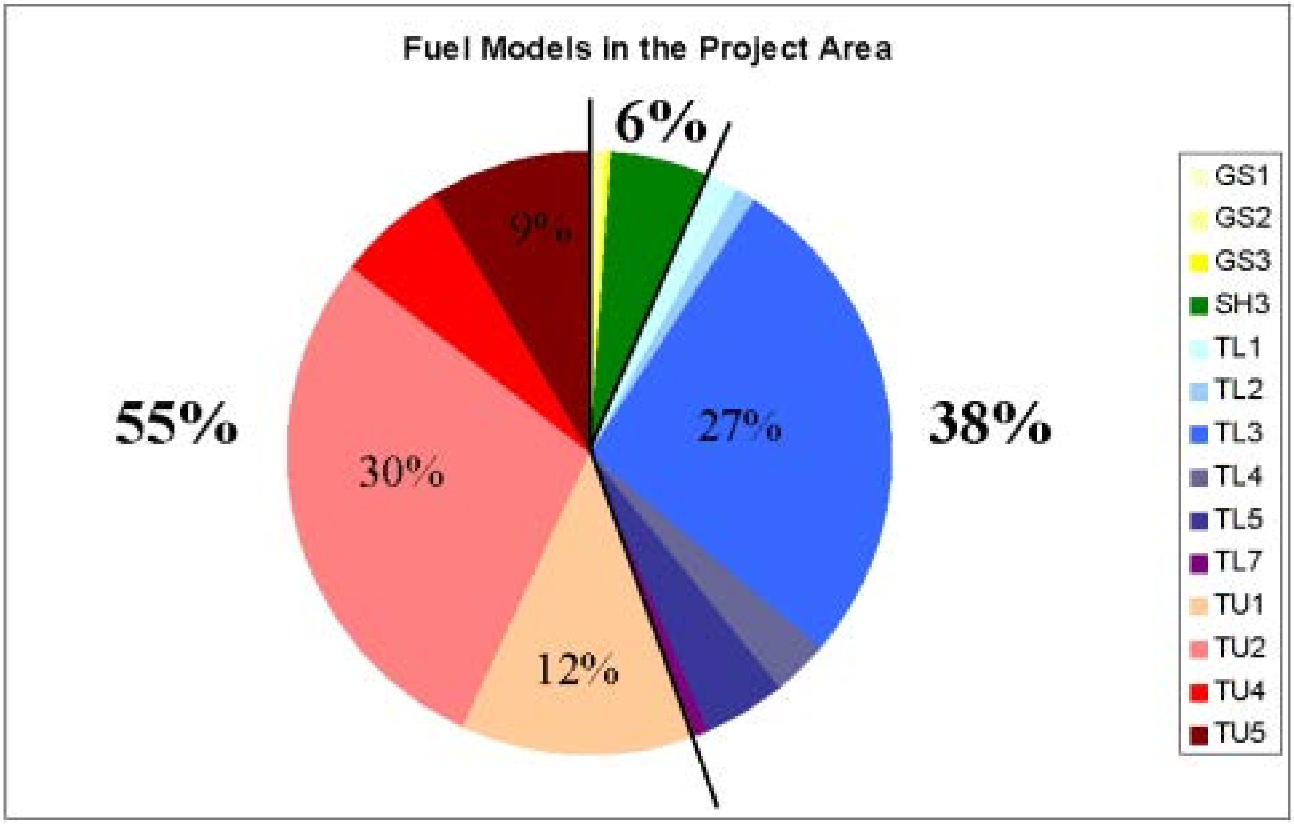

Figure 14. Pie chart of fire behavior fuel model occurrence in the project area.

We found 14 of the 40 Scott and Burgan (2005) fire behavior fuel models in the project area (Figures 13 and 14, Table 4). A little more than half the plots fit into the timber understory (TU) model types, while most of the remaining plots were deemed to fit the timber litter (TL) models (Figure 14). Scott and Burgan organized their fuel models based on major fuel type (e.g. grass, shrub, timber litter, slash) and then by two climate types. Their fuel models are split into either an “arid to semiarid climate” type (with extinction moisture content of 15 percent), or a “subhumid to humid climate” type (with extinction moisture content of 30-40 percent). This climate-based categorization leaves a gap (extinction moisture content of 15-30 percent). Unfortunately, the microclimates in the Mt. Spokane study area are often midway between a semi-arid and a sub-humid climate. In part, because of the fact that the Scott and Burgan fuel models do not cover this gap adequately, we selected fuel models from both the dry climate group and the wet climate group, depending on which fuel model best described the situation at each forest survey plot. We also often assigned the plot to two fuel models, one the dominant type and a secondary type. Table 4 briefly describes the fuel models in the project area.

Table 4. Primary Fire Behavior Fuel Model in the Project Area

Code	General Fuel Model Type	Description of General Fuel Model Type	Specific Description	Climate Type
GS1	Grass-Shrub	Mixture of grass and shrub, up to about 50 percent shrub coverage	Shrubs are about 1 foot high, low grass load. Spread rate moderate; flame length low.	Arid to semiarid climate (rainfall deficient in summer)
GS2	Grass-Shrub	Mixture of grass and shrub, up to about 50 percent shrub coverage	Shrubs are 1 to 3 feet high, moderate grass load. Spread rate high; flame length moderate.	Arid to semiarid climate (rainfall deficient in summer)
GS3	Grass-Shrub	Mixture of grass and shrub, up to about 50 percent shrub coverage	Moderate grass/shrub load, average grass/shrub depth less than 2 feet. Spread rate high; flame length moderate.	Subhumid to humid climate (rainfall adequate in all seasons)
SH3	Shrub	Shrubs cover at least 50 percent of the site; grass sparse to nonexistent	Moderate shrub load, possibly with pine overstory or herbaceous fuel, fuelbed depth 2 to 3 feet. Spread rate low; flame length low.	Subhumid to humid climate (rainfall adequate in all seasons)
TU1	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is low load of grass and/or shrub with litter. Spread rate low; flame length low.	Semiarid to subhumid climate.
TU2	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is moderate litter load with shrub component. Spread rate moderate; flame length low.	Humid climate.
TU4	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is short conifer trees with grass or moss understory. Spread rate moderate; flame length moderate.	Semiarid to subhumid climate.
TU5	Timber-Understory	Grass or shrubs mixed with litter from forest canopy	Fuelbed is high load conifer litter with shrub understory. Spread rate moderate; flame length moderate.	Semiarid to subhumid climate.
TL1	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed is recently burned but able to carry wildland fire. Light to moderate load, fuels 1 to 2 inches deep. Spread rate very low; flame length very low.	No climate modifier
TL2	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed composed of broadleaf (hardwood) litter. Low load, compact. Spread rate very low; flame length very low.	No climate modifier
TL3	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed does not include coarse fuels. Moderate load conifer litter. Spread rate very low; flame length low.	No climate modifier
TL4	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed includes both fine and coarse fuels. Moderate load, includes small diameter downed logs. Spread rate low; flame length low.	No climate modifier
TL5	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed does not include coarse fuels. High load conifer litter; light slash or mortality fuel. Spread rate low; flame length low.	No climate modifier
TL7	Timber Litter	Dead and down woody fuel (litter) beneath a forest canopy	Fuelbed includes both fine and coarse fuels. Heavy load, includes larger diameter downed logs. Spread rate low; flame length low.	No climate modifier

Forest Canopy Cover
Forest canopy cover (Figure 15) represents the amount of the sky that is covered by a forest canopy. It is one of the most important indicators of forest condition and determines the amount of light that understory vegetation and fuels on the forest floor receive. It also is a primary determinant of wind speed and air movement in the forest understory and at the forest floor.

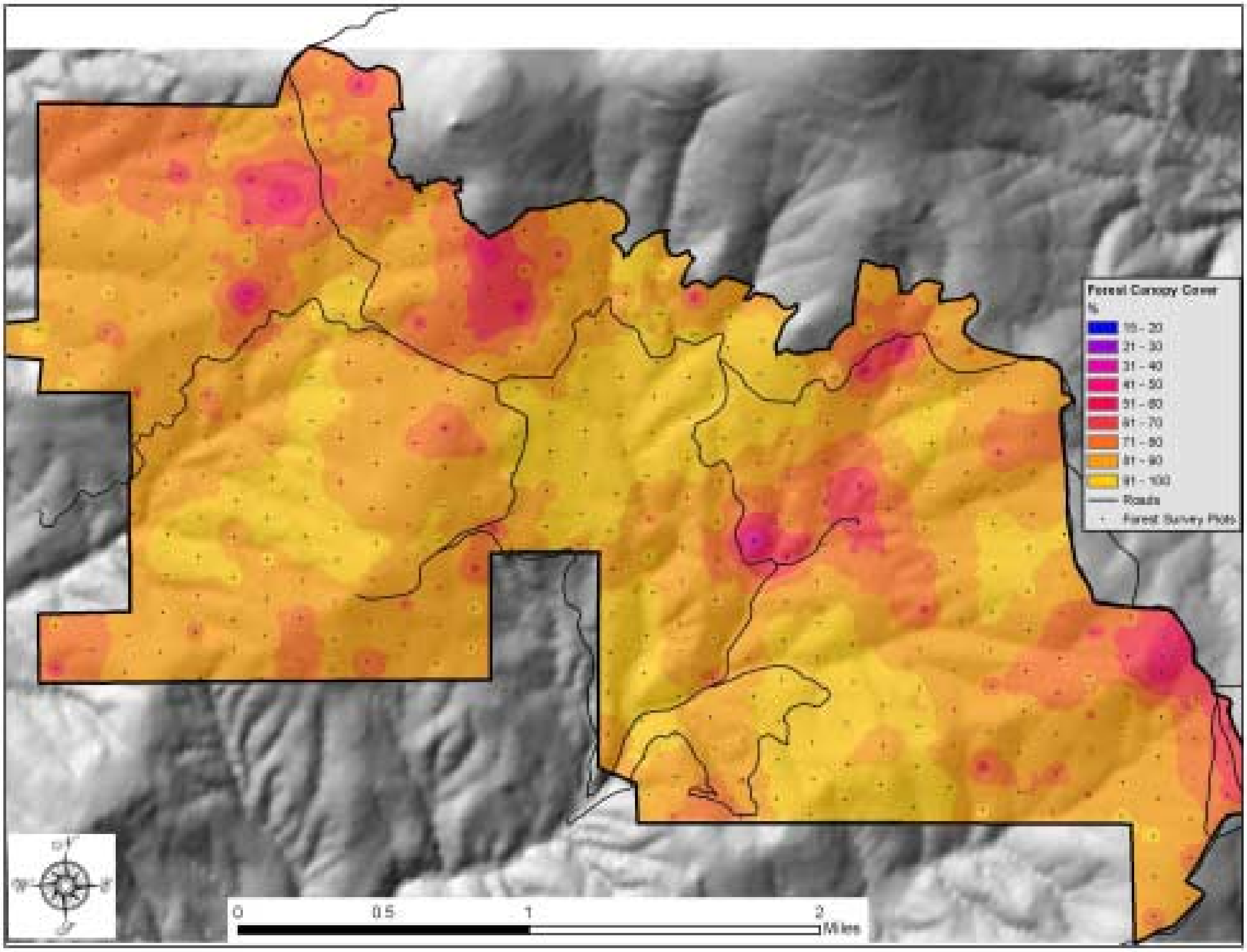

Figure 15. Forest canopy cover in the project area.

Canopy Bulk Density

Canopy bulk density is an important crown characteristic needed to predict crown fire spread, yet it is difficult to measure in the field (Keane et al 2005). Canopy bulk density is a measure of the fuel density (measured in kg/cubic meter) in the forest canopy. It is the accumulation of the crown bulk densities within a forest stand (Figure 16) that is an indicator of the canopy bulk density (and thus fuel load) in that stand.

Tree-level | **Stand-level**

Crown bulk density and Crown base height | **Canopy bulk density and Canopy base height**

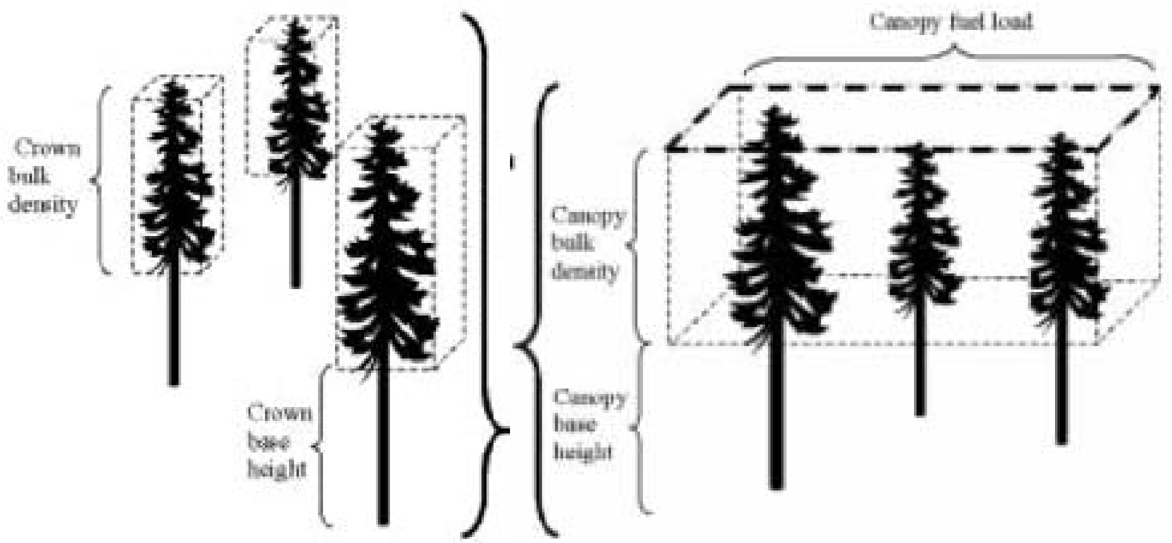

Figure 16. Illustration of crown and canopy bulk density and crown and canopy base height. (From Cruz et al 2003)

Crown bulk density is the primary factor that controls the rate of spread needed to achieve active crown fire (Figure 17). Therefore it is an important dimension of forest condition to estimate and use in wildfire modeling and prediction. We created a canopy bulk density GIS raster surface layer for the study area (Figure 18) using methods described in Cruz et al (2003) by calculating the crown bulk density of each individual tree and summing these for the stand on a per acre basis. These values were then interpolated to the entire project area landscape using the IDW technique.

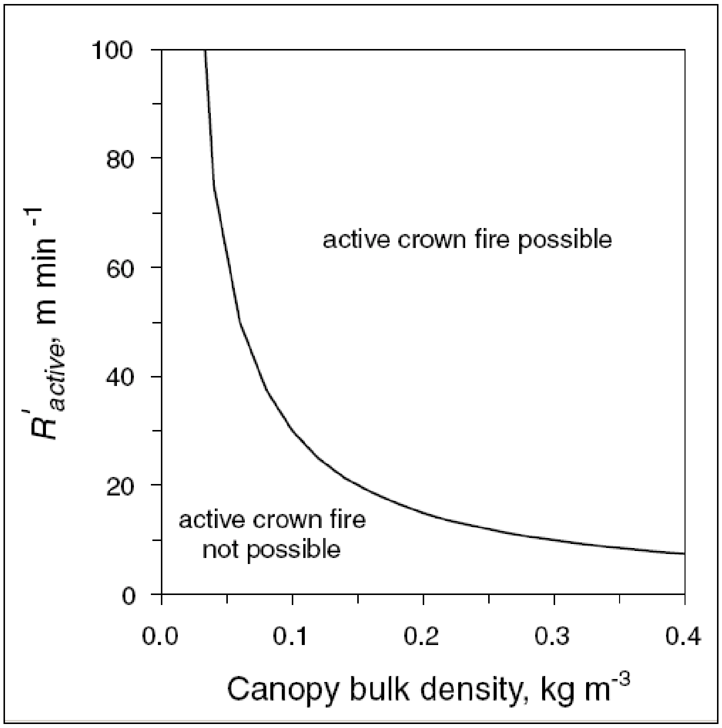

Figure 17. Van Wagner's criterion for sustained active crown fire spread based on a minimum horizontal mass-flow rate of 0.05 kg m^{-2} min^{-1}. Example: a stand with CBD of 0.2 kg m-3 requires a spread rate of 15.0 m min-1 to sustain active crowning. (From Scott and Reinhardt 2001).

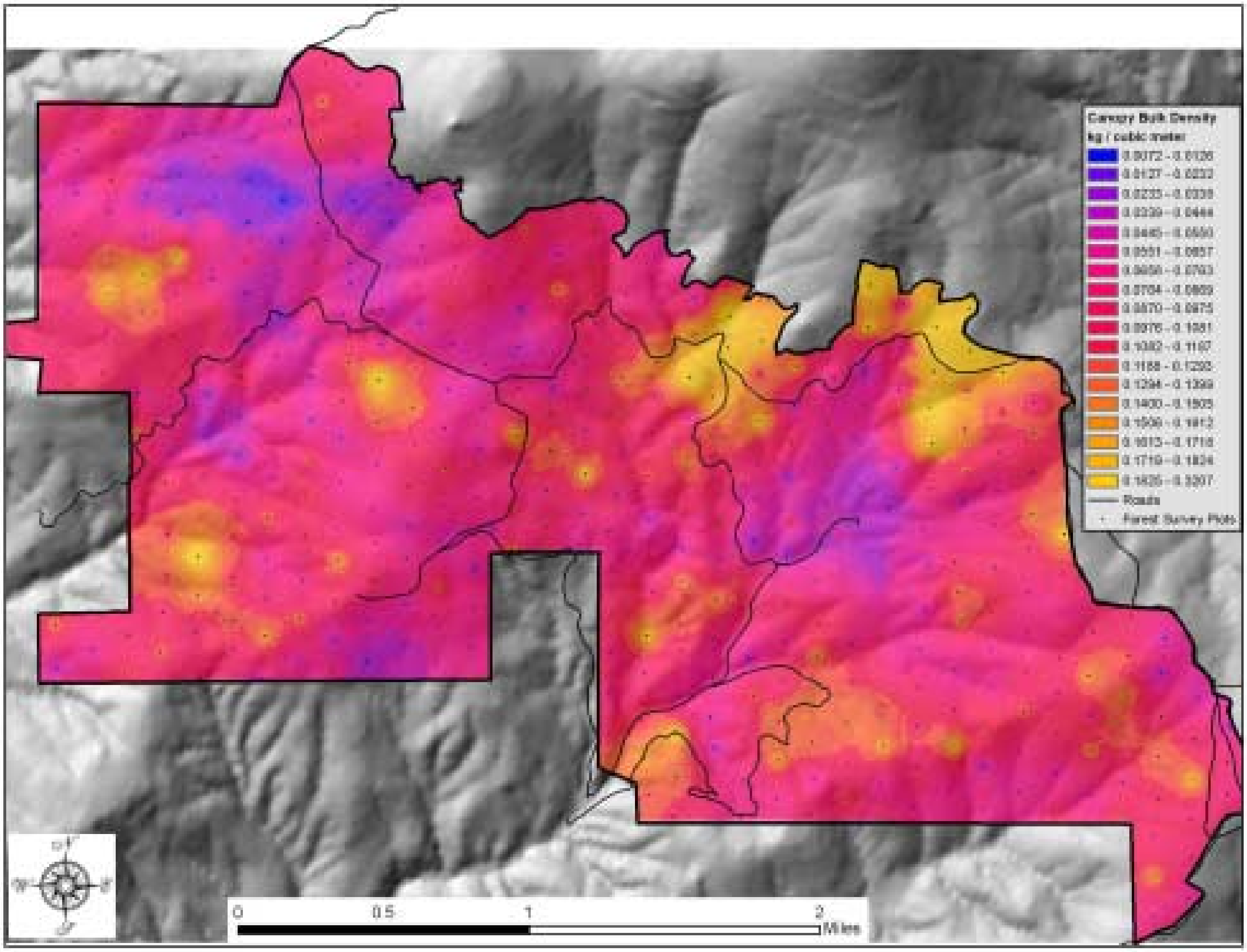

Figure 18. Canopy bulk density in the project area. (trees > 4 inches DBH)

Canopy Height

The height of the forest canopy (Figure 19) is another important forest stand attribute. It can be one of the determinants of wildlife habitat for certain species. It is also an important factor in fire behavior and forest successional processes. It is determined by averaging the height of the dominant and co-dominant trees in the stand.

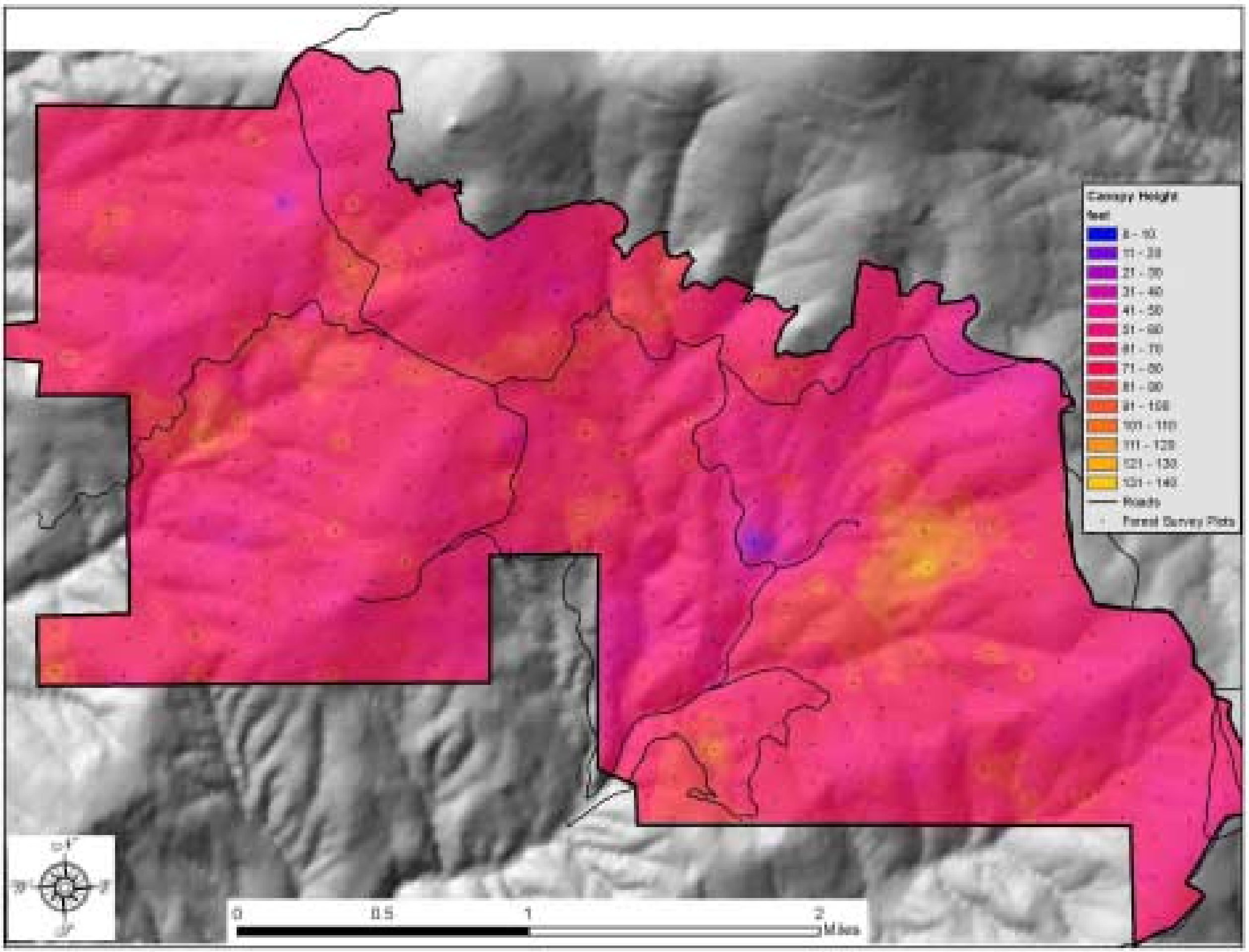

Figure 19. Mean canopy height in the project area. (trees > 4 inches DBH)

Canopy Base Height

The canopy base height (Figures 16 and 20) is another important forest stand attribute. It is also an important factor in fire behavior and forest successional processes. It can be used along with canopy height to help determine wildlife habitat for certain species. It is determined by averaging the crown base height (Figure 16) of the all the trees in the stand.

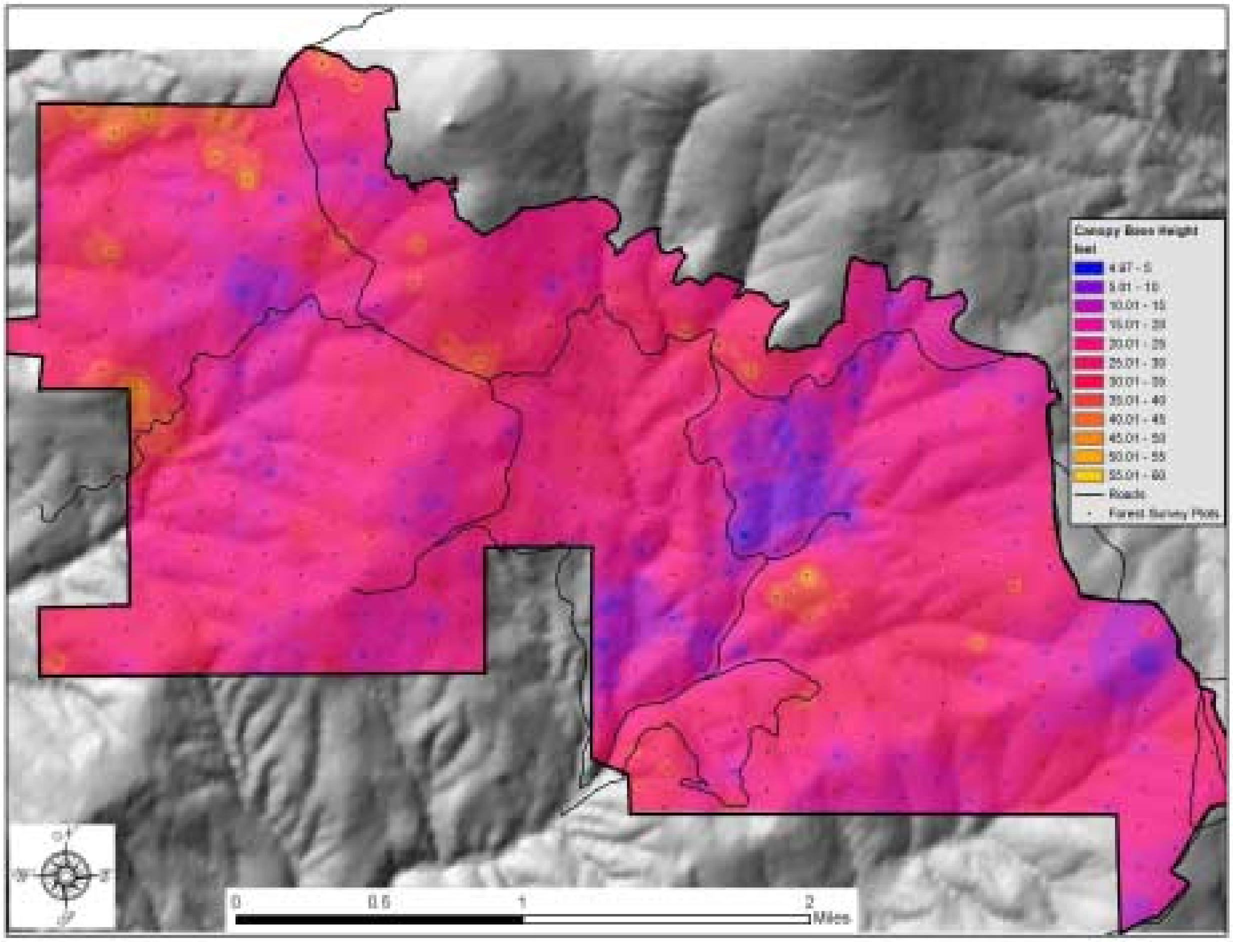

Figure 20. Mean canopy base heights in the project area. (trees > 4 inches DBH)

The following discussion from Scott and Reinhardt (2001) is helpful in understanding complexity in measuring and computing canopy base height:

"Crown base height is a simple characteristic to measure on an individual tree. Canopy base height (*CBH*) is not well defined or easy to estimate for a stand. Neither the lowest crown base height in a stand nor the average crown base height is likely to be representative of the stand as a whole. Canopy base height is difficult to measure in multistory stands and stands with ladder fuels. Van Wagner (1993) reduced (the)observed *CBH* to account for ladder fuels in a two-story stand. Defined in terms of its consequences to crown fire initiation, *CBH* is the lowest height above the ground at which there is sufficient canopy fuel to propagate fire vertically through the canopy. Using this definition, ladder fuels such as lichen, dead branches, and small trees are incorporated. Sando and Wick (1972) estimated canopy base height of nonuniform stands based on the height at which a minimum bulk density of fine fuel (100 lb acre-1 ft-1, 0.037 kg m-3) is found. The Fire and Fuels Extension to the Forest Vegetation Simulator (Beukema and others 1997) uses the Sando and Wick approach in combination with Brown's (1978) equations to estimate canopy base height and canopy bulk density. Canopy base height was defined as the lowest height above which at least 30 lb/acre/ft (0.011 kg m-3) of available canopy fuels is present. Ladder fuels that increase the intensity of the surface fire, such as short understory trees, shrubs, and needle drape, are best accounted through custom surface fuel modeling or by simple adjustment of simulated surface fire intensity to include their effect."

In the Mt. Spokane project area we were conservative in our estimate of canopy base height, since we measured the crown base height of each tree at the lowest significant live branches. This places the crown base height below the level described above. Therefore, our calculation of canopy base height for the stands is lower than what would be indicated from a calculation that included consideration of the amount of canopy fuel above a given height. Those measurements were beyond the scope of our contract.

Canopy base height is one of the most important variables in determining crown fire initiation (Figure 21). When crown base heights of trees in a stand are low, then low fireline intensities and low flame lengths are sufficient to initiate crown fires under various fuel moisture conditions.

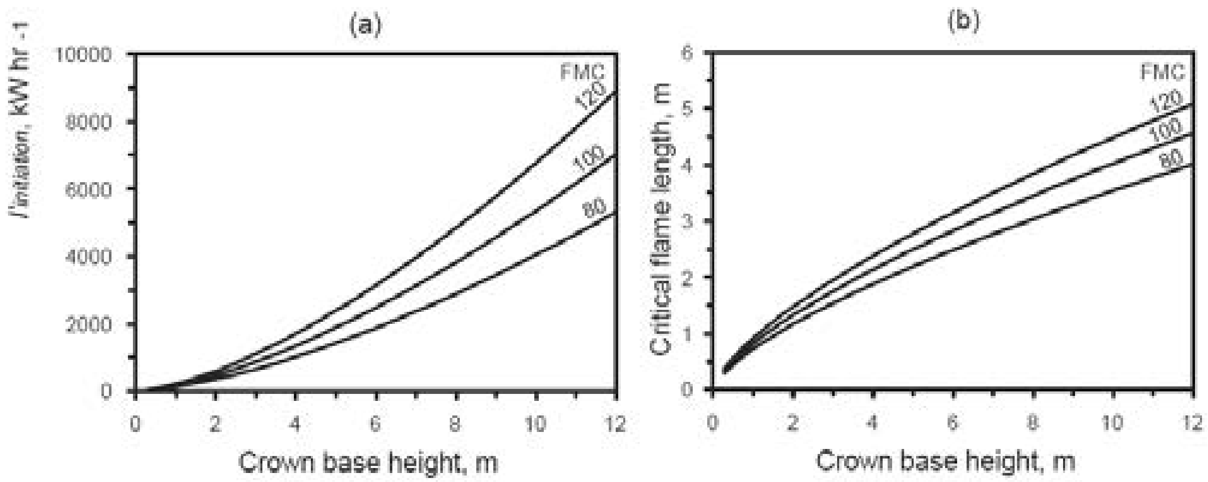

Figure 21. Van Wagner's crown fire initiation criterion (following Alexander 1988) expressed as critical surface fireline intensity (a), and critical flame length using Byram's (1959) flame length model (b). Note that critical flame length is less than canopy base height (CBH) for CBH greater than about 1 m. Example: a stand with CBH of 3 m and 100 percent fuel moisture content (FMC) requires surface fireline intensity of 875 kW m-1 (flame length 1.7 m) to initiate crowning.

Tree Density

The density of trees in a stand (stem density) is another important measure of forest condition. It is calculated by determining the number of tree stems per unit area (Figure 22). Our calculation of tree density was based on trees sampled in the variable radius plots, and so it does not include the smallest trees. These were tallied separately. High-density stands often have intense competition between trees for sunlight, water and nutrients. This often results in eventual mortality of the less competitive trees. Low-density stands often have ample room for trees to grow, however there may be very dense shrub understories and intense competition in the understory.

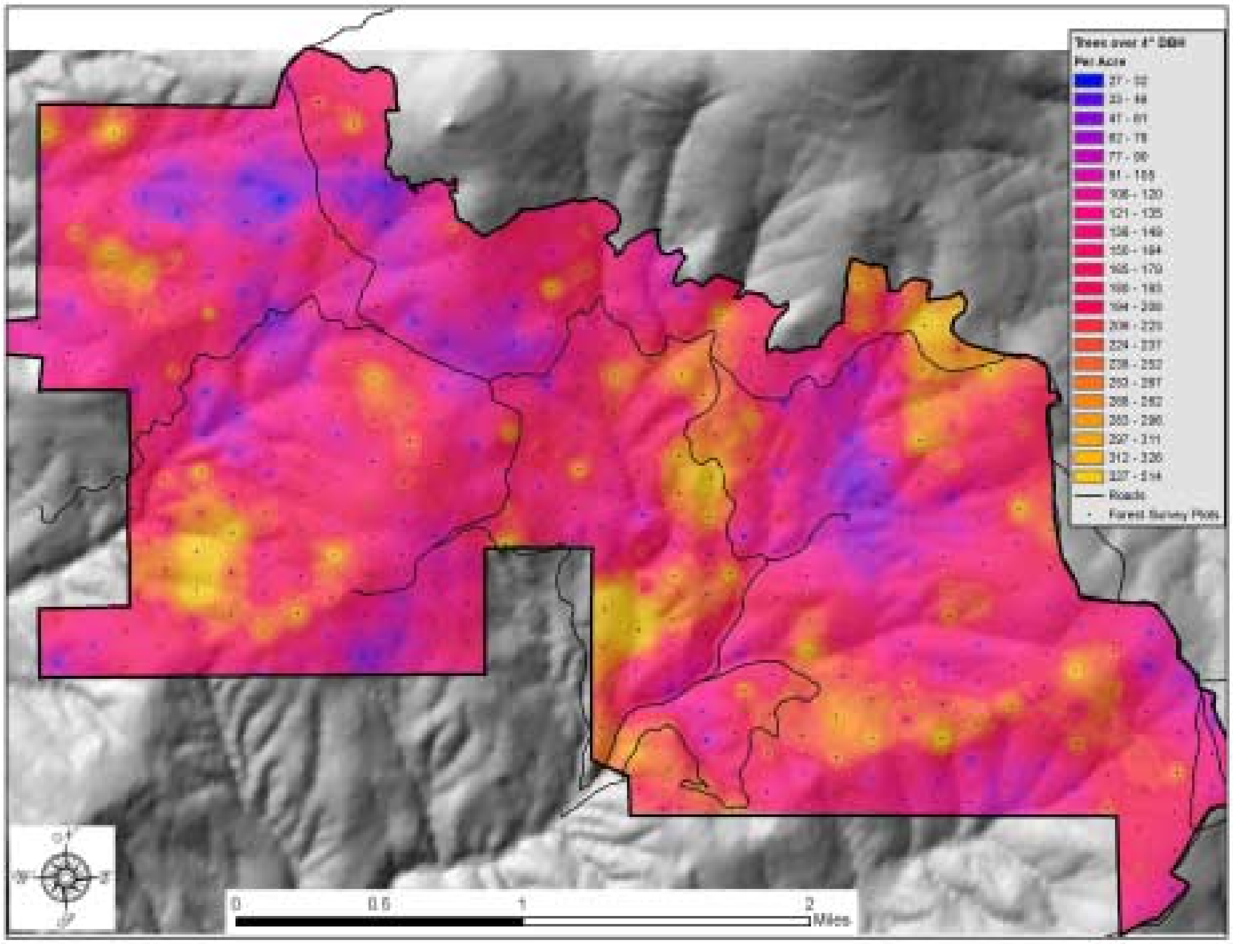

Figure 22. Tree density in the project area. (trees per acre > 4 inches DBH)

Basal Area

Basal area is simply a measure of the cross-sectional area of each stem, in this case the stems of the live trees. We calculated the basal area of each tree and then summed these values on a per acre basis for each forest survey plot. Figure 23 illustrates basal area as it varies throughout the project area as determined by IDW interpolation from the plot data. Basal area is one of the factors that determine the total biomass in a forest stand.

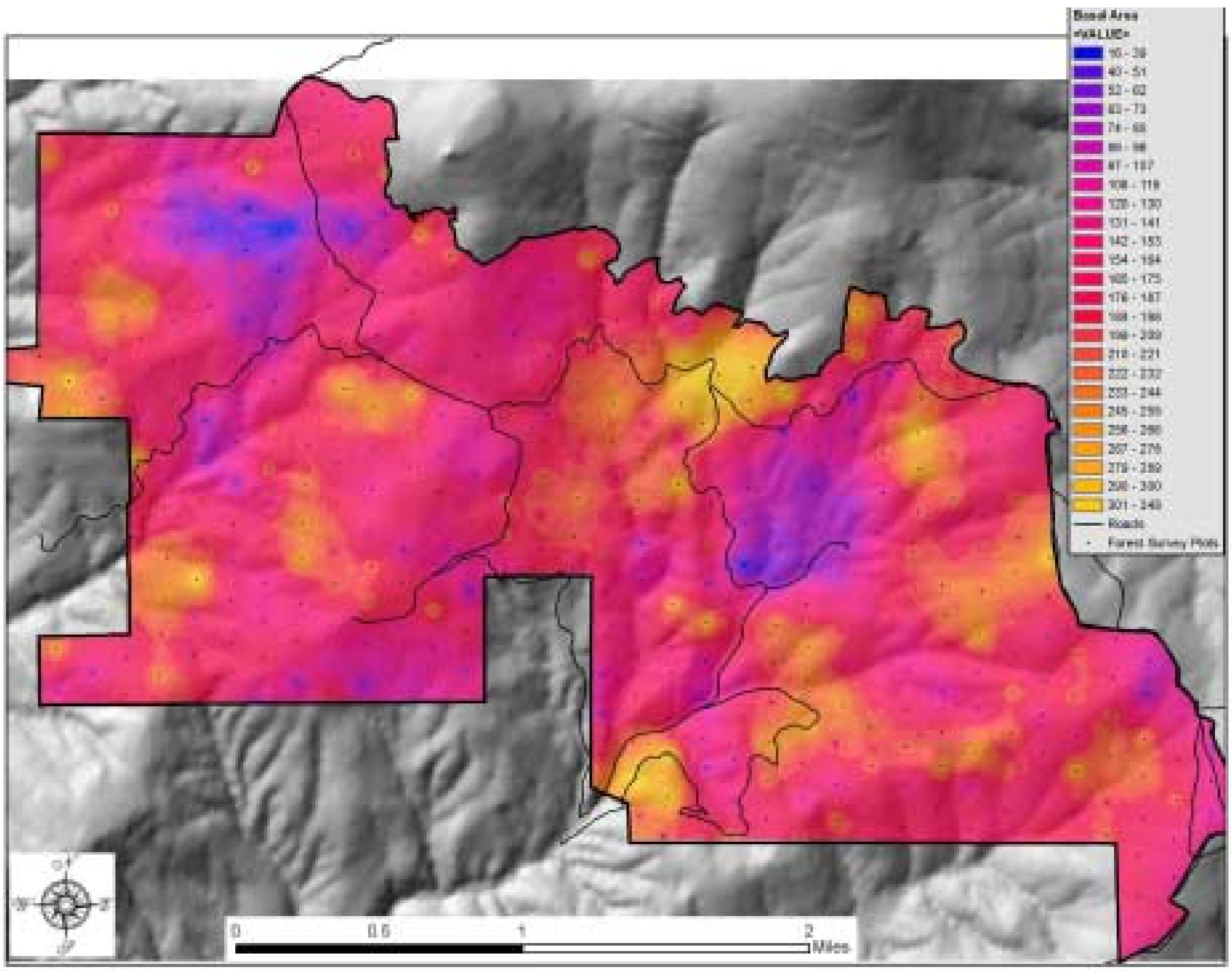

Figure 23. Stand basal area throughout the project area. (square feet/acre for trees > 4 inches DBH)

Tree Diameters

The project area has a wide range of successional stages of stands - quadratic mean diameter is one expression of the size and age of a forest stand. The quadratic mean diameter is the diameter of the tree with the arithmetic mean basal area (cross-sectional area) (Husch et al 1982). It is a more meaningful measure of the stand diameter than the simple mean diameter and is illustrated in Figure 24. Graphs of the actual diameter distribution of all the plots are provided in Appendix M.

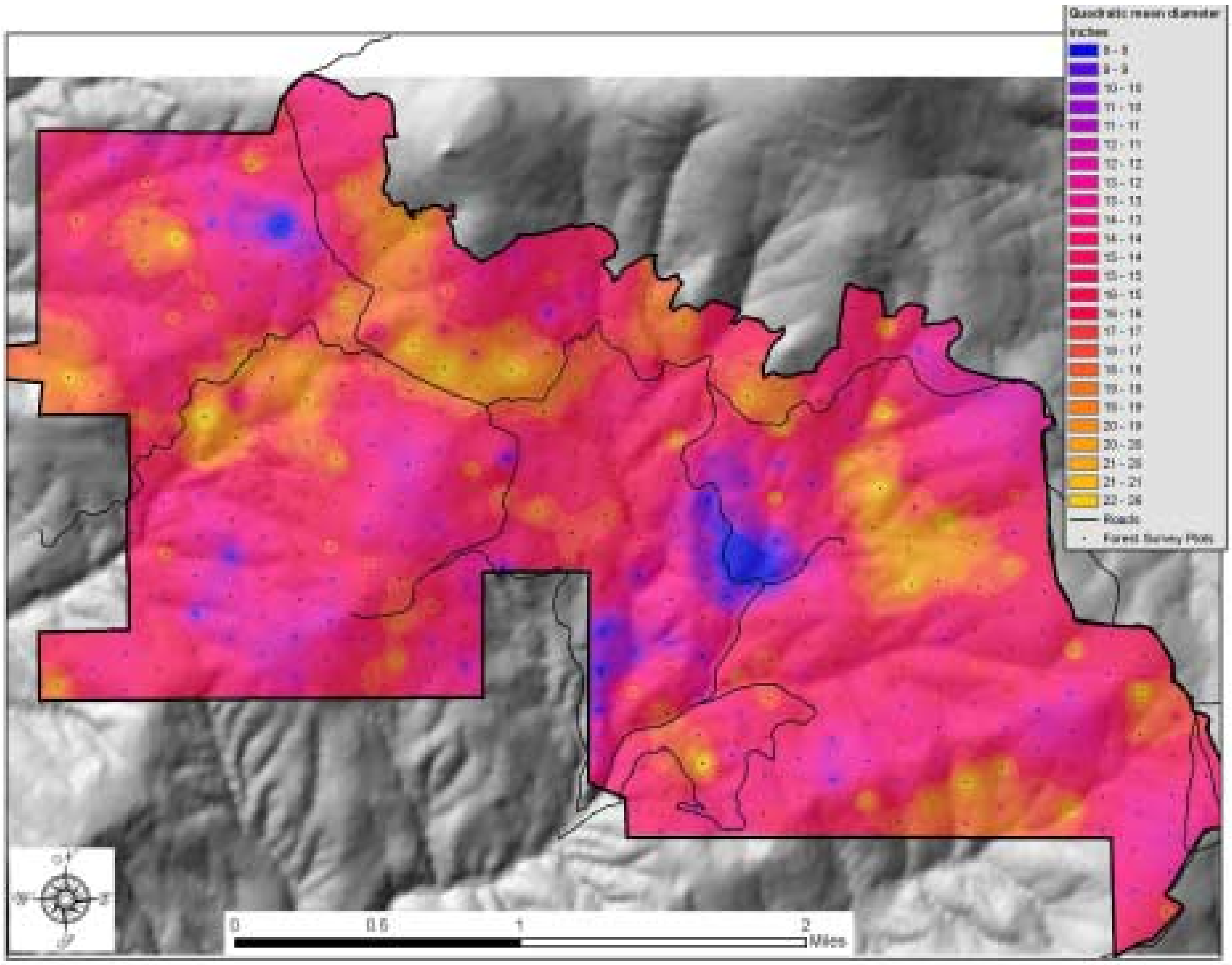

Figure 24. Quadratic mean diameter of forest stands in the project area. (trees > 4 inches DBH)

Stand Density Index

Stand density index (SDI) is a measure of relative stand density, allowing comparisons between stands comprised of different species and diameters (Husch et al 1982). We calculated SDI using a new method developed by Woodall and Miles (2004) from our plot data and the result is depicted in Figure 25. Stand density index (SDI) was originally developed for use in even-aged monocultures, but has been used more recently for stand density assessment in large-scale forest inventories. Woodall and Miles (2004) improved the application of SDI in uneven-aged, mixed species stands present in large-scale inventories, through development of a model whereby a stand's maximum SDI was calculated as a function of the stand's mean specific gravity (SG) of individual trees.

SDI is usually not strongly correlated with age or site index. This quality of independence of age and site makes SDI a valuable parameter in describing a stand. We did find that it was highly correlated with basal area in our project area.

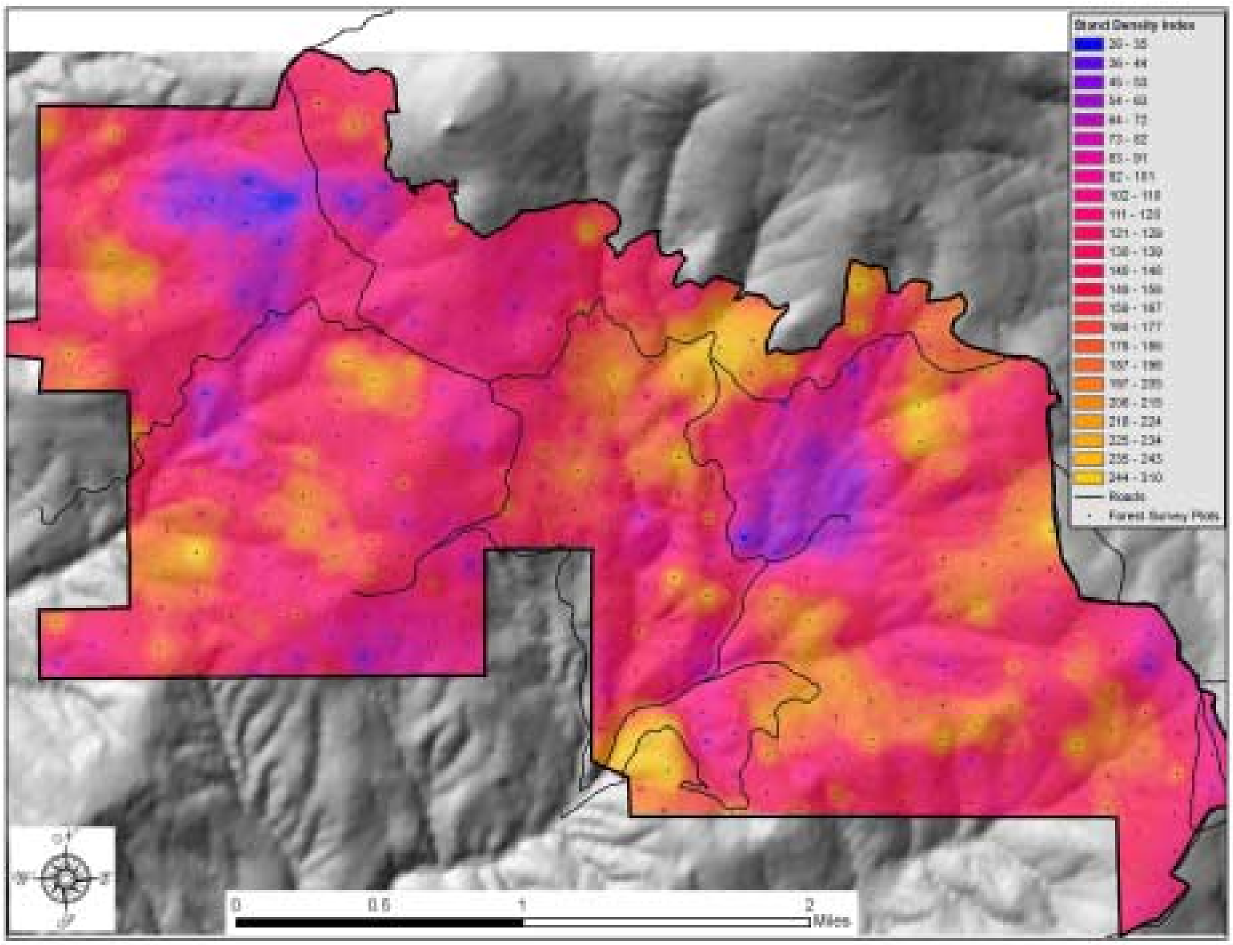

Figure 25. Stand density index in the project area. (trees > 4 inches DBH)

Tree Species Composition and Diversity

Figures 26-28 depict examples of the variation in tree density by various conifer species. The three species chosen (ponderosa pine, western larch and Douglas-fir) are the most fire resistant species in the project area. These species are also diminishing in abundance compared to pre-settlement conditions. Figure 29 illustrates Shannon's diversity index, which is a measure of overall tree species diversity. The formula for Shannon's diversity index is:

$$H = -\sum_{i=1}^{S} p_i \log p_i$$

where p_i is the fraction of individuals belonging to the i-th species. This is by far the most widely used diversity index. It is much more informative than a simple measure of species richness because it accounts for both the overall richness of species and the relative abundance of those species.

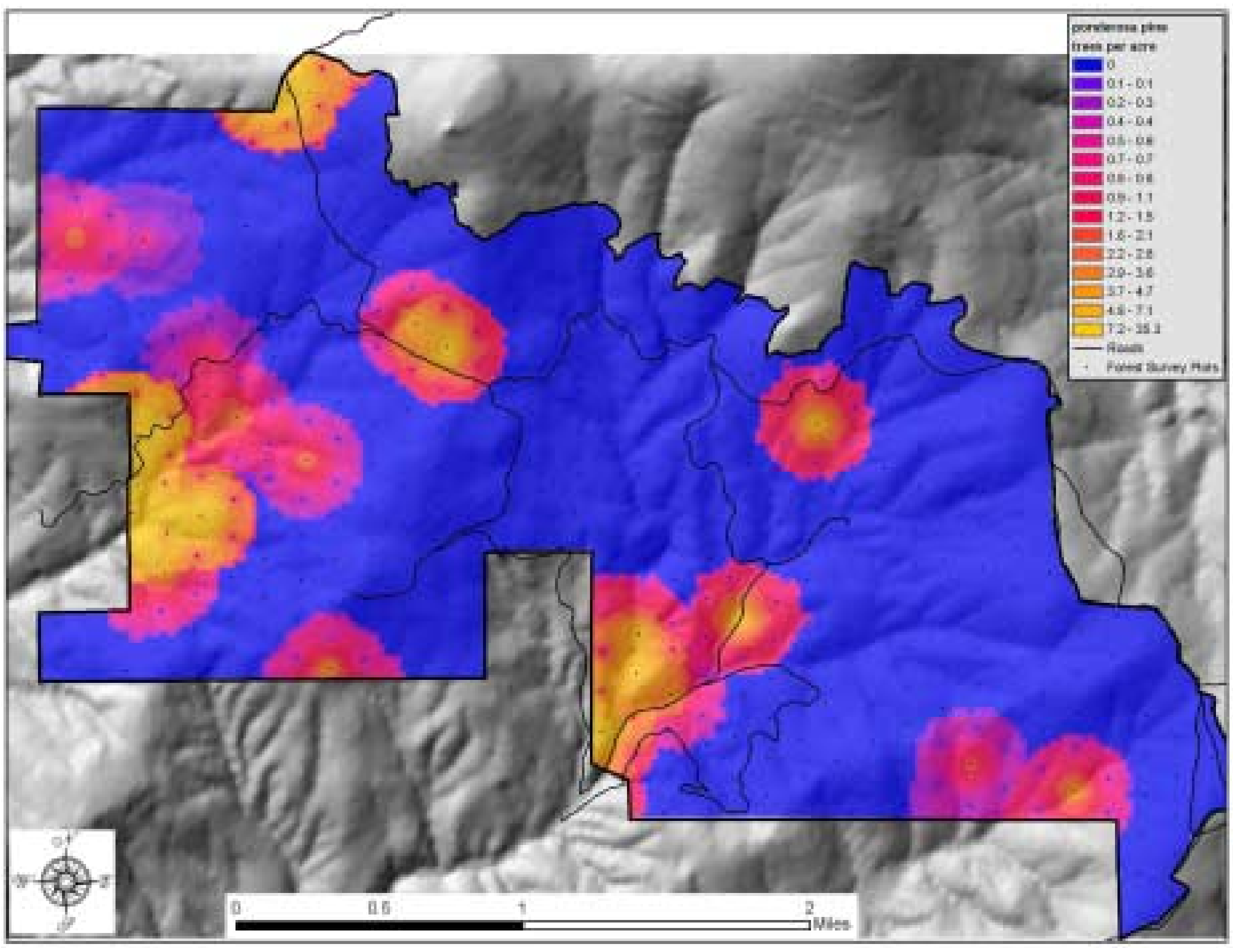

Figure 26. Ponderosa pine density (trees per acre) in the project area. (trees > 4 inches DBH)

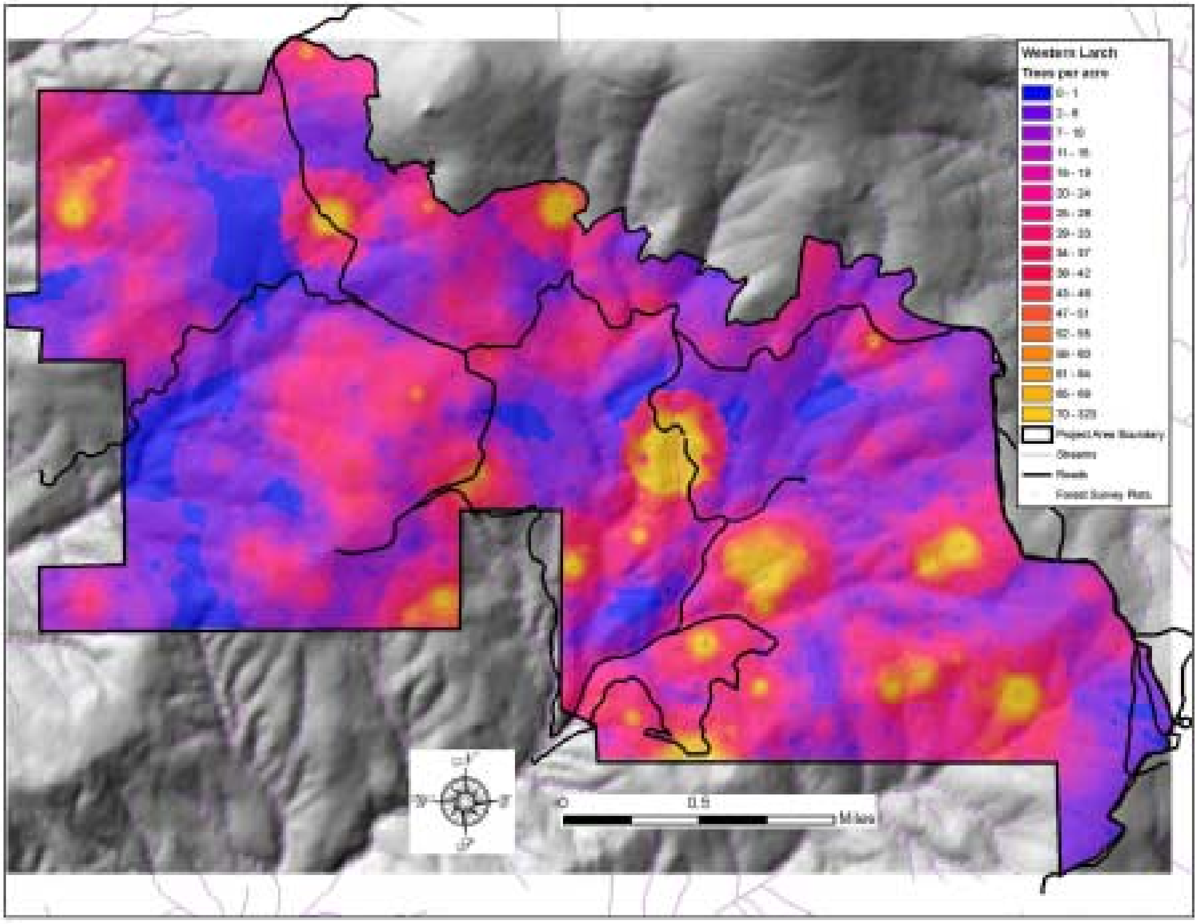

Figure 27. Western larch density (trees per acre) in the project area. (trees > 4 inches DBH)

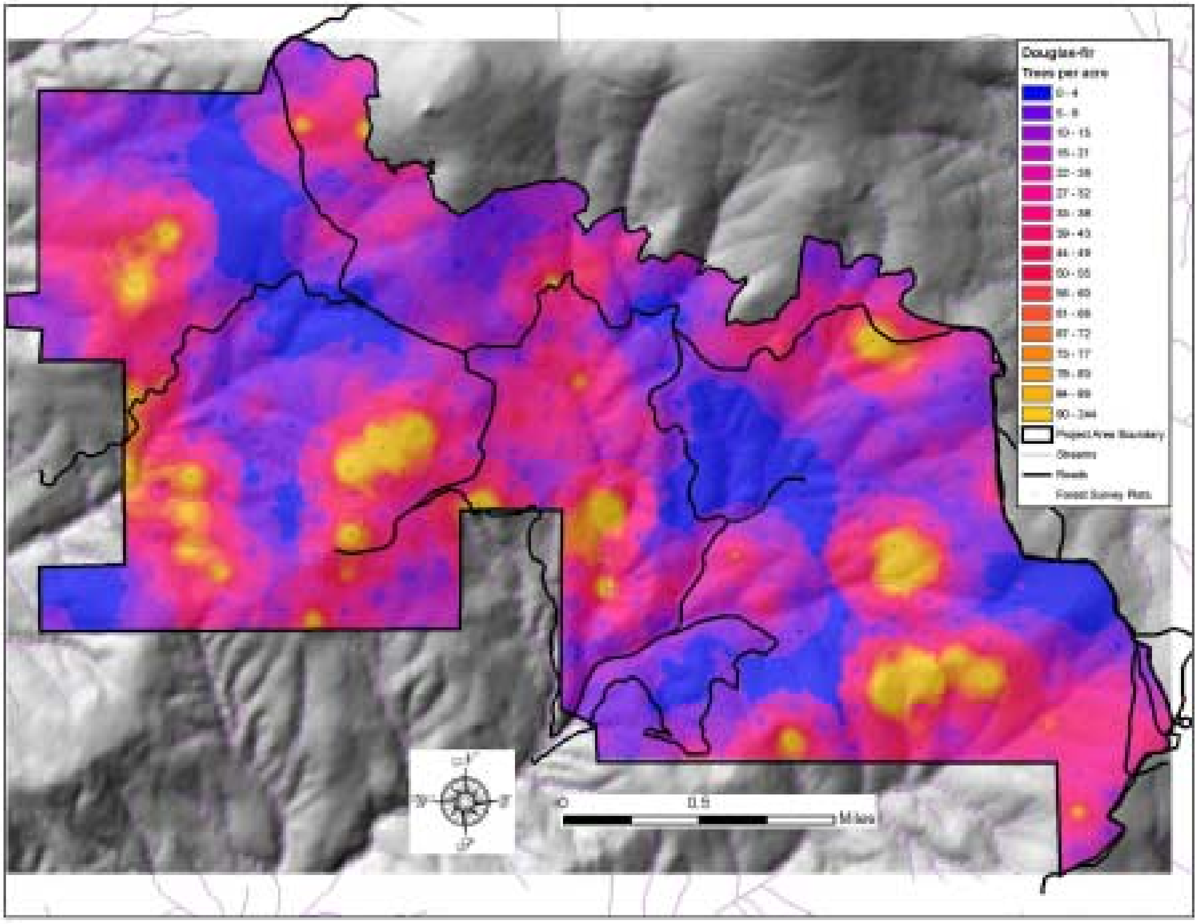

Figure 28. Douglas-fir density (trees per acre) in the project area. (trees > 4 inches DBH)

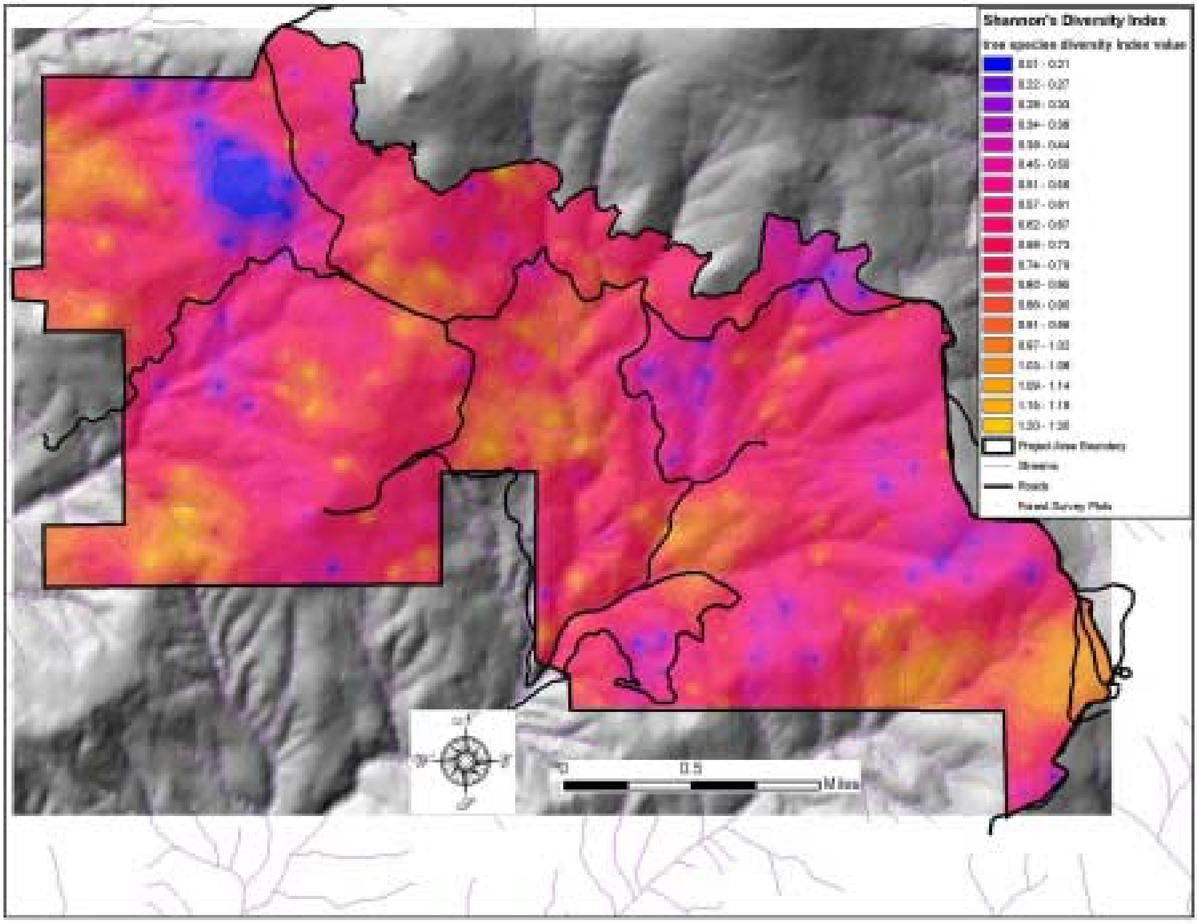

Figure 29. Shannon's Diversity Index in the project area. **(trees > 4 inches DBH)**

Distribution of Old-growth Forests

The distribution of old-growth forests at Mt. Spokane is an important factor in determining forest health conditions, especially with regard to wildlife habitat conditions. We explored a variety of ways of assessing the degree of old-growth forest development in the project area. We developed an indicator of old-growth forest development called "MaxDBH." The indicator is being based in part on prior methods of identifying and mapping old growth forests in the Pacific Northwest (Franklin and Spies 1984; Old-growth Definition Task Group 1986; Morrison 1988, 1990; Morrison et al 1990, 1991). These old-growth definitions and mapping methods uses a minimum density of stems per acre of a minimum diameter size as one of the parameters needed to classify stands as old growth or mature forests. In these prior studies, the value of eight trees per acre was used as the minimum density to classify a stand as old-growth. In our case, we are trying to determine the degree of development of old-growth or late-successional forest condition in a stand based on the same premise. However, since old-growth definitions are not well established for eastern Washington forests, we are not as concerned with a minimum diameter size threshold for identifying actual old-growth forests as we are about identifying the degree of development toward old-growth conditions.

From our adaptation of this indicator, we can see the general size of the presumed dominant or co-dominant cohort in a given area (the largest diameter class that has at least 8 trees per acre in the stand), as one indicator of stand age and development. For instance, if a forest stand has a MaxDBH value of 24 (inches), we can presume that there are at least 8 trees per acre in that stand that have a DBH of 24 inches or more. We also know that there are less than 8 trees per acre in any diameter class above 24, so we are presuming that at least 24-inch diameter trees are constantly occurring throughout the stand and that these trees would yield the best information as to the age of the oldest dominant cohort. A stand with a MaxDBH value of 24 might have seven trees per acre of 32 inches DBH, but not enough of the higher diameter classes to amount to eight trees per acre. Therefore it is just a rough indicator of the overall size distribution of the stand. Quadratic mean diameter (described above) is another indicator of the overall size distribution of a stand, but it accounts for the diameter of all the trees, not just the largest trees. Therefore, MaxDBH is a useful additional forest condition indicator and was used in subsequent wildlife habitat modeling (Figure 30). Graphs of the actual diameter distribution of all the plots are provided in Appendix M.

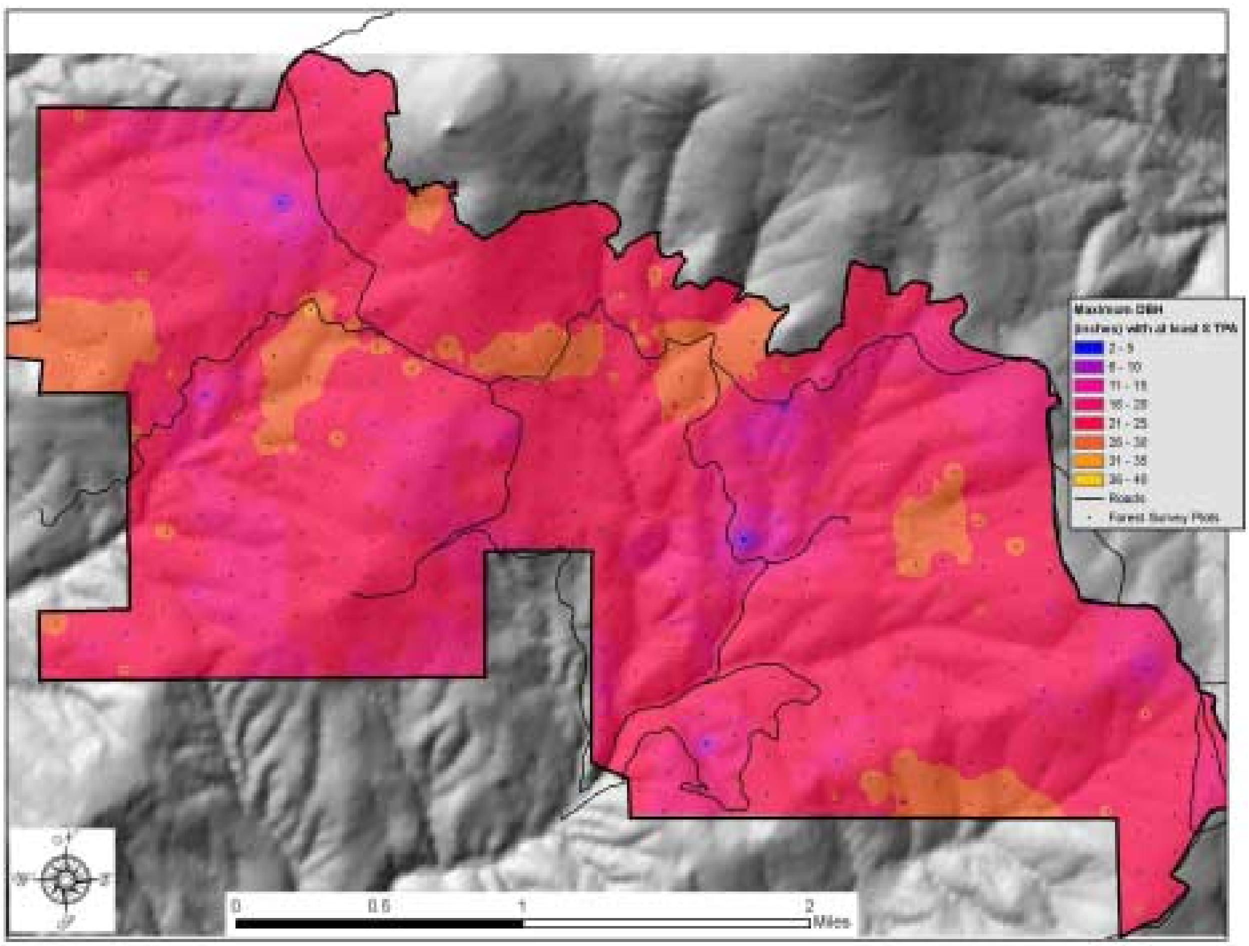

Figure 30. MaxDBH: the largest tree diameter classes possessing at least 8 trees per acre in the stands throughout the project area. (trees > 4 inches DBH)

Distribution of Snags

There is a wide variation in snag density, size, decay class and composition in project area. The illustration below (Figure 31) shows the number of snags in the project area. Other snag parameters (size, decay class and species) were also recorded and used in analyses. Snags are an important habitat component for many wildlife species.

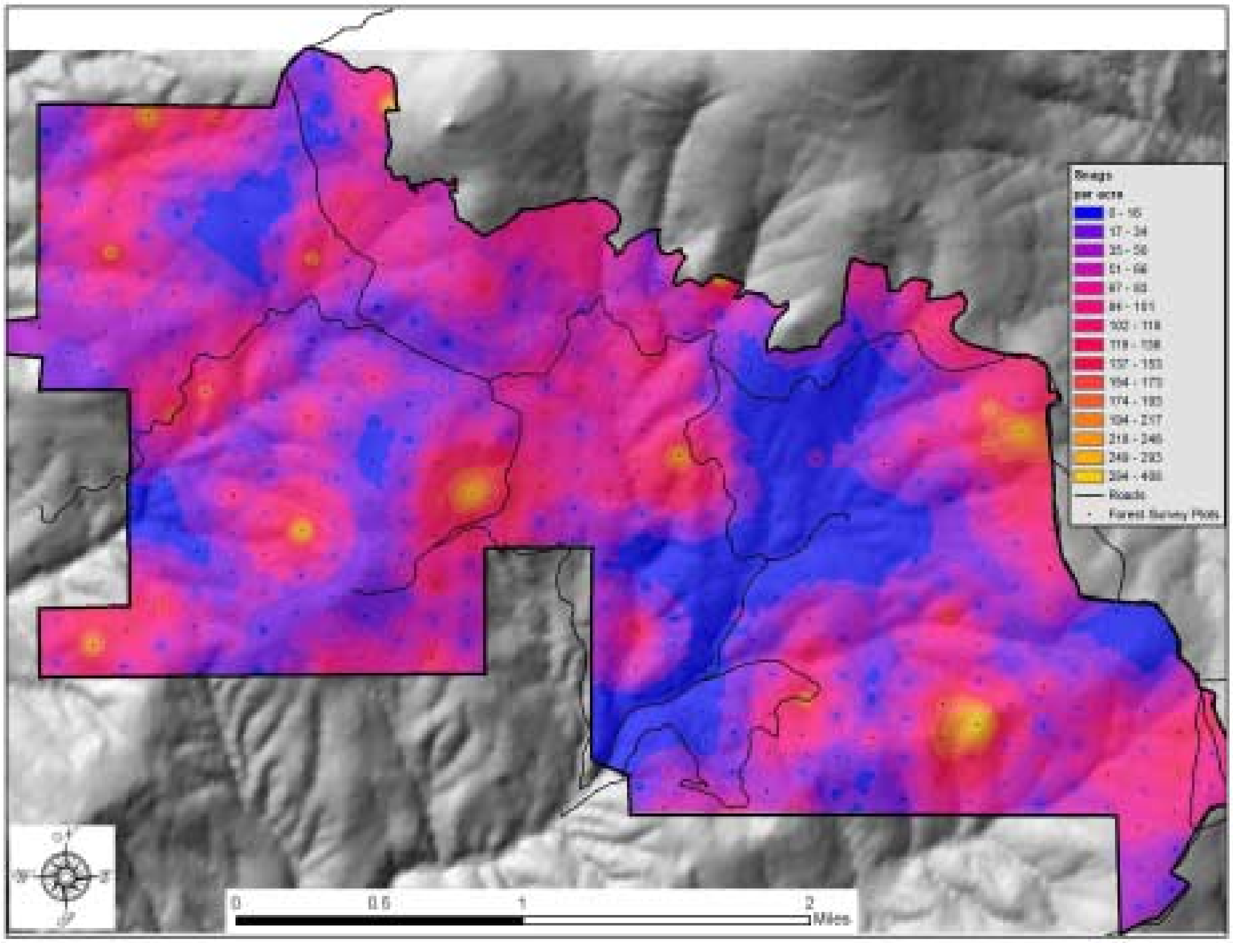

Figure 31. Snag density in the project area. (snags per acre for snags > 4 inches DBH)

Distribution of Coarse Woody Debris

Figure 32 illustrates the amount of ground surface area covered by coarse woody debris (CWD) in the project area. Most of the project area has CWD covering less than 10% of the ground surface. But some areas have CWD covering over 50% of the ground surface.

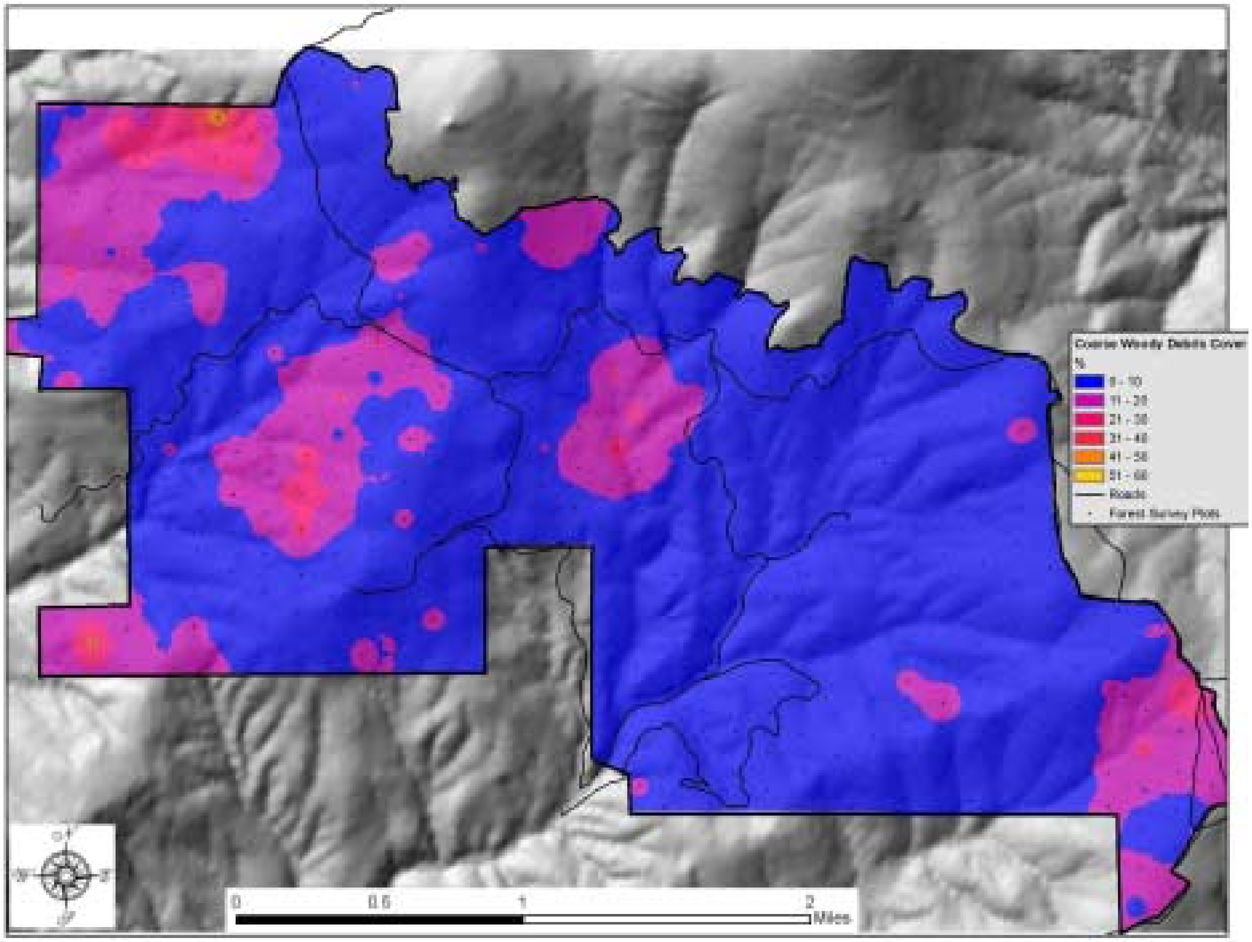

Figure 32. Coarse woody debris cover in the project area. (logs >6 inch diameter)

The number of pieces of coarse woody debris (CWD) in the project area is very variable (Figure 32). While much of the project area has less than 100 pieces of CWD (logs >6 inch diameter) per acre, some areas have densities of over 400 piece of CWD per acre. The presence of coarse woody debris is important habitat component for many wildlife species.

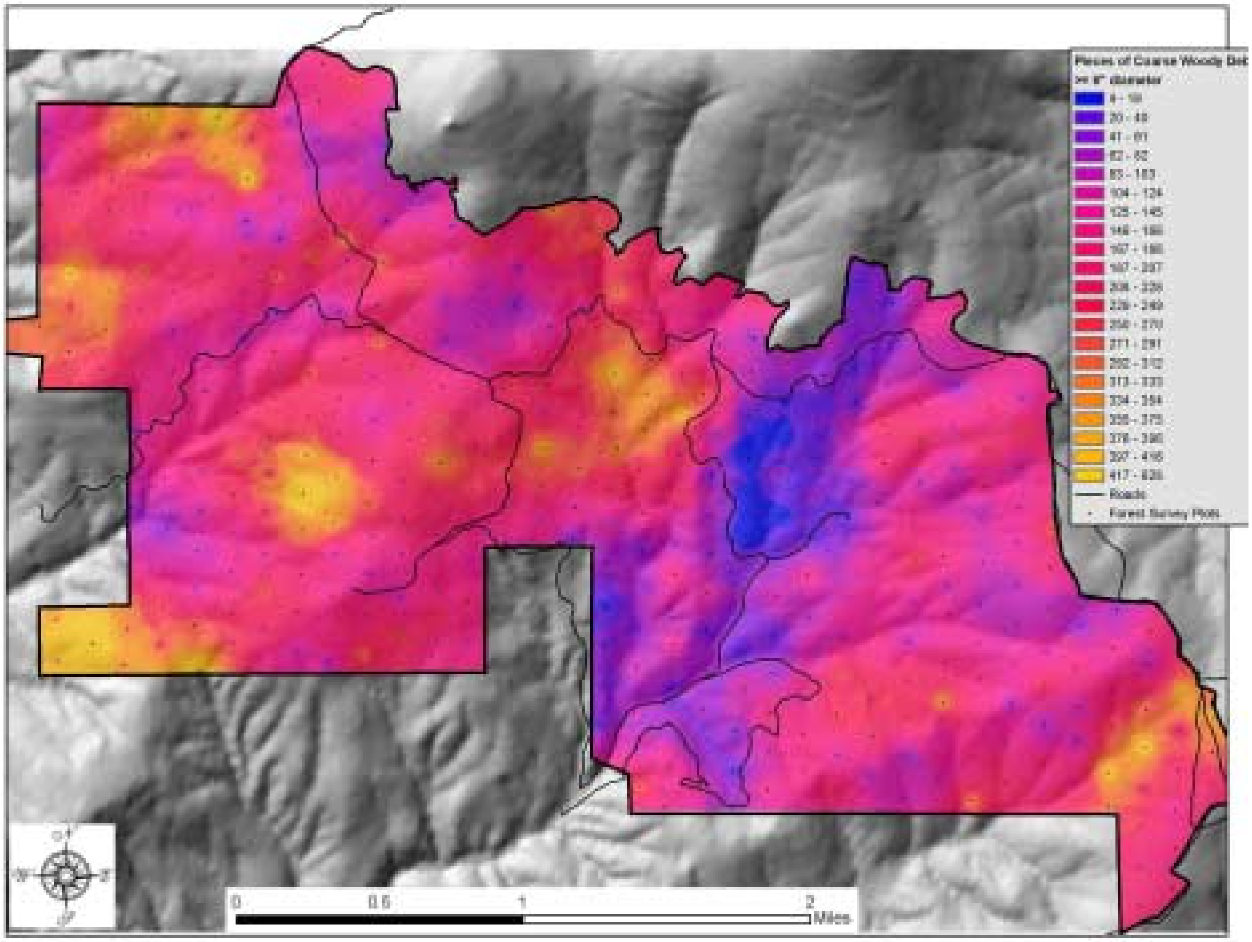

Figure 33. Coarse woody debris density in the project area. (logs >6 inch diameter per acre)

Distribution of Shrubs

There is a wide variation in shrub cover in the study area (Figure 34). Shrub cover influences wildlife habitat, fire behavior and forest successional dynamics.

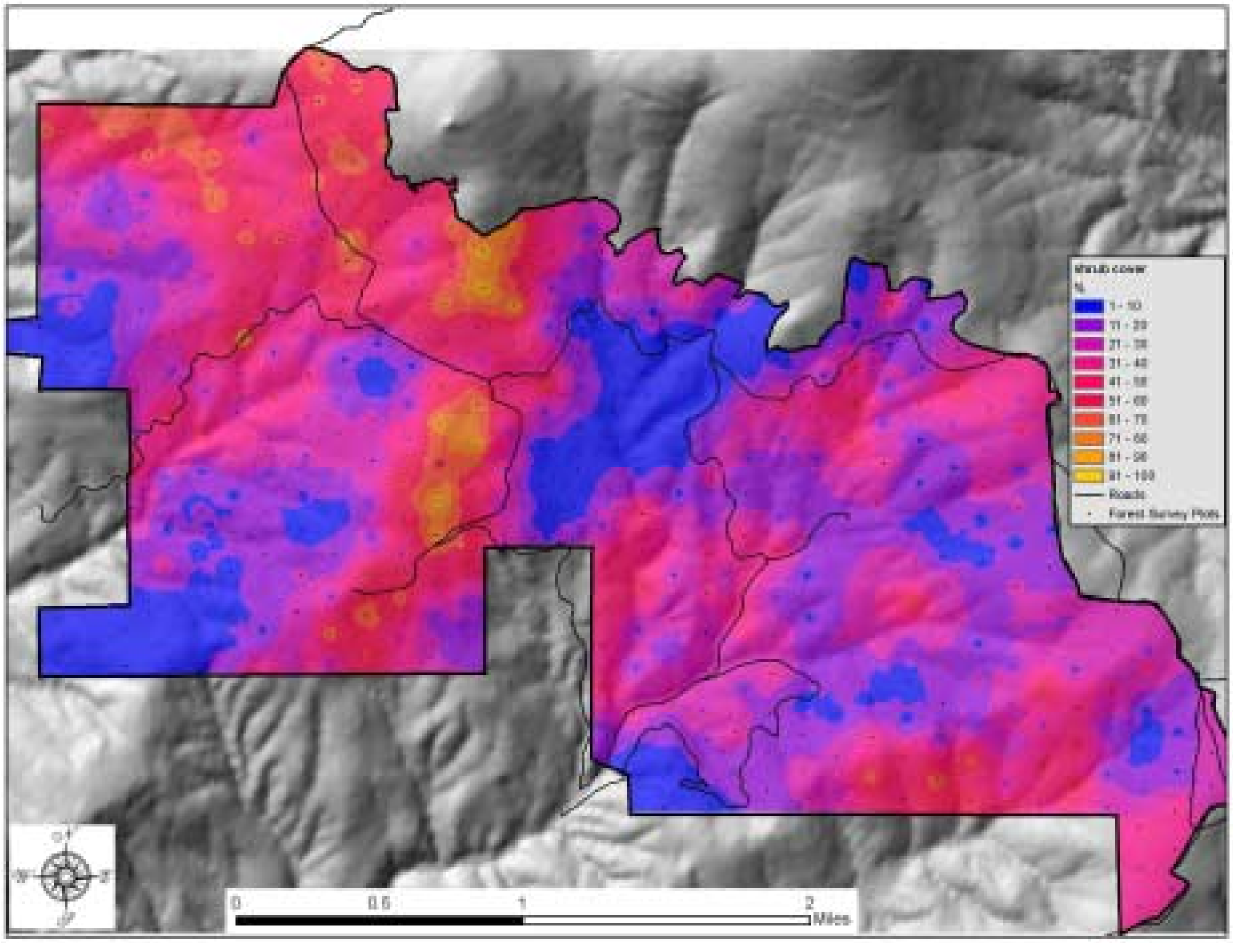

Figure 34. Shrub cover in the project area. (based on the three dominate understory species in each plot)

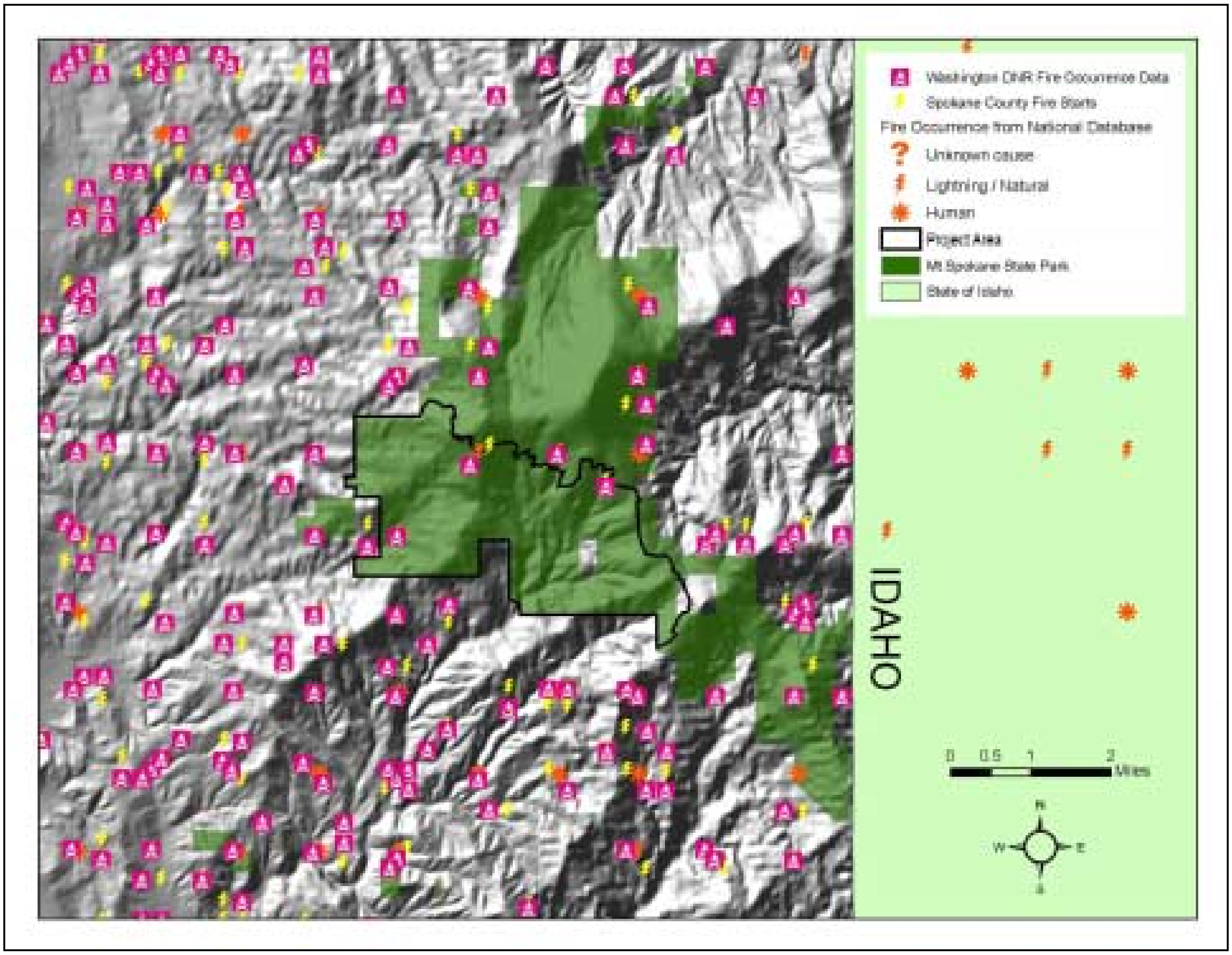

Figure 63. Fire occurrences in the Mt. Spokane vicinity since 1970 from various state and federal databases.

Information gained from review of fire ecology literature

An excellent treatment of the fire ecology of the forest types found at Mt. Spokane is provided by Smith and Fisher (1997). They divided the forest habitat types of northern Idaho into nine “fire groups.” The plant communities we found in the Mt. Spokane project area are fairly similar to some of the habitat types that have been described in northern Idaho (Cooper et al 1991).

The dominant plant communities in our project area are several grand fir associations that Smith and Fisher (1997) group into their Fire Group Seven, which characterizes the fire ecology of moderate and moist grand fir habitat types. In Idaho, this fire group has a highly variable fire regime with fire intervals ranging from 18 year to over 800 years. Most sites where fire history studies were conducted had mean fire return intervals of at least 50 years, with nearly half the sites having mean fire return intervals of over 100 year. Sites in the grand fir mosaic habitat type often recorded no fires and the mean fire return interval is estimated to exceed the life of the seral trees. Fire-related forest succession is usually dominated by Douglas-fir, western larch, ponderosa pine, lodgepole pine, western white pine and grand fir. As succession proceeds grand fir becomes more and more dominant. If fire is excluded from these stands for two to three centuries, the early seral species decline, leaving an old-growth stand of grand-fir and scattered other species (Smith and Fisher 1997).